SUPPLEMENT

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CITY AND GUILDS OF LONDON INSTITUTE EXAMINATIONS, 1967-68

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QUESTIONS AND ANSWERS

Answers are occasionally omitted or reference is made to earlier Supplements in which questions of substantially the same form, together with the answers, have been published. Some answers contain more detail than would be expected from candidates under examination conditions.

PRACTICAL MATHEMATICS, 1968 (*continued*)

Q. **9.** *Draw with the same axes and scales the graphs of* $2y + 3x = 12$, $3y = 2x + 5$ *and* $y = \frac{6}{x}$.

(*a*) *What is common to all three graphs?*
(*b*) *State*
(*i*) *the slope of each straight line,*
(*ii*) *the angle between the straight lines.*
(*c*) *Assign a name to each straight line with respect to the hyperbola.*

A. **9.** $2y + 3x = 12$

or, $2y = 12 - 3x$,

i.e. $y = 6 - \frac{3x}{2}$.

This is of the form $y = mx + c$, i.e. it will have a straight-line graph and may be plotted from a minimum of two points, but preferably from three to serve as a check.

As it is not known in advance where this graph will intersect the other two, assuming it will, it will be advisable to take a fairly wide range of x-values in order to plot the graph. On the other hand, the question requires all graphs to be plotted to the same scales and this suggests that the range should be restricted. In such a case it is probably best to plot a rough graph as a preliminary in order to obtain a suitable range. It will be found that the range in the following table of values will suffice:

x	-3	0	3
$\frac{3x}{2}$	$-\frac{9}{2}$	0	$\frac{9}{2}$
$y = 6 - \frac{3x}{2}$	$10\frac{1}{2}$	6	$1\frac{1}{2}$

$3y = 2x + 5$

or, $y = \frac{2x}{3} + \frac{5}{3}$.

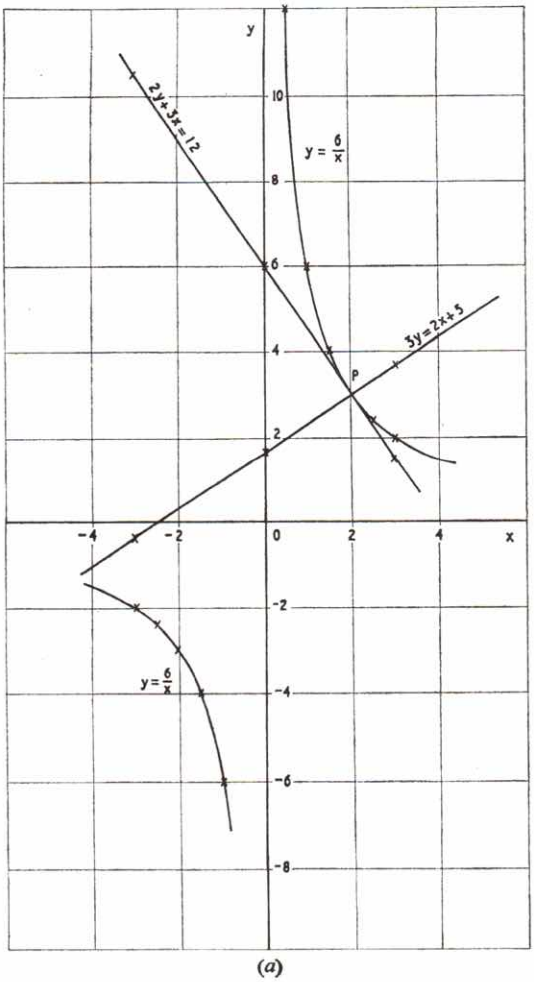
This again will have a straight-line graph and is plotted from the same range of x-values as the previous graph.

x	-3	0	3
$\frac{2x}{3}$	-2	0	2
$y = \frac{2x}{3} + \frac{5}{3}$	$-\frac{1}{3}$	$\frac{5}{3}$	$\frac{11}{3}$

$y = \frac{6}{x}$

This is not a straight-line law and hence it is necessary to plot a fairly large number of points in order to produce a smooth curve. The graph is plotted from the following table of values.

x	-3	$-2\frac{1}{2}$	-2	$-1\frac{1}{2}$	-1	$-\frac{1}{2}$	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3
y	-2	$-2\frac{2}{5}$	-3	-4	-6	-12	∞	12	6	4	3	$2\frac{2}{5}$	2



(*a*)

The three graphs are shown drawn to the same axes and same, equal, scales in sketch (*a*).

(*a*) A common feature of the graphs is that they all intersect at the point P (2, 3).

(*b*) (*i*) The slope of $2y + 3x = 12$ is $-3/2$, and that of $3y = 2x + 5$ is $2/3$.

(*ii*) The angle between the straight lines is a right-angle.

If two lines are at right-angles then the product of their slopes is -1, in this case the product $= -\frac{3}{2} \times \frac{2}{3} = -1$.

(*c*) The line $2y + 3x = 12$ is a tangent to the hyperbola $y = \frac{6}{x}$ whilst the line $3y = 2x + 5$ is a normal to curve.

Note.—It has been assumed that the examiner intended parts (*a*), (*b*) and (*c*) to be answered graphically and not by any other means. This being so, the question should have stipulated that the graphs be drawn with the same, equal, scales, as has been done in sketch (*a*). If the scales are not equal the angle between the straight lines will not be a right-angle and neither will it be obvious that the line $3y = 2x + 5$ is normal to the curve.

Q. 10. *During the charging of an accumulator the specific gravity x of the electrolyte was recorded every hour. With scales 0·01 = 1 in. for x and 2 hour = 1 in. for the time t, use the table of values to plot x against t.*

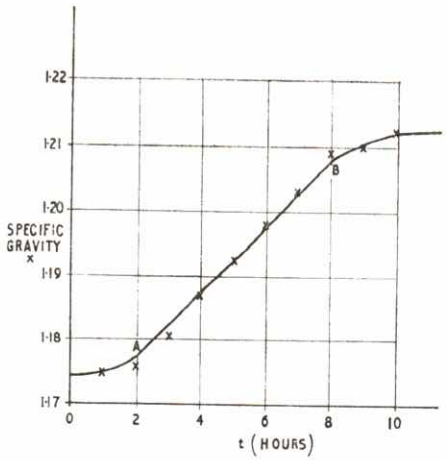
State the values of t between which the law $x = at + b$ is approximately true and obtain from your graph values for a and b.

t hours	1	2	3	4	5
x	1·175	1·176	1·181	1·187	1·193

t hours	6	7	8	9	10
x	1·198	1·203	1·209	1·210	1·212

A. 10. The graph is plotted to the appropriate scales in sketch (*a*). The student should note that although *x* values are ordinarily plotted along the horizontal axis, in this particular case they must be plotted along the vertical axis. This is because the values of specific gravity *x* are observed or recorded values, whereas those of time were chosen.

It is seen that the graph is substantially a straight line between $t = 2$ and $t = 8$ hours. Therefore the law $x = at + b$ follows over this range of values.



(*a*)

The gradient of the straight-line is *a* and may be obtained by measurement from the graph. Taking the values of the coordinates at points A and B on the graph,

$$a = \frac{1·2083 - 1·1762}{8 - 2},$$
$$= \frac{0·0321}{6}$$
$$= 0·00535.$$

To obtain the value of the constant *b*, the coordinates of any suitable point on the straight-line portion of the graph are substituted into the equation $x = at + b$, together with the value of *a* obtained above.

Taking the coordinates of *A*,

$$1·1762 = 0·00535 \times 2 + b.$$
$$\therefore\ b = 1·1762 - 0·0107$$
$$= 1·1655.$$

Hence, $a = 0·00535$ and $b = 1·1655$.

ENGINEERING SCIENCE, 1968

Students were expected to answer two questions from *Q.* 1–4 and four from *Q.* 5–10.

Q. 1. *Describe one method you could use to decide whether a number of forces, of known magnitude and direction, are in equilibrium.*

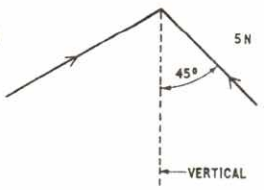
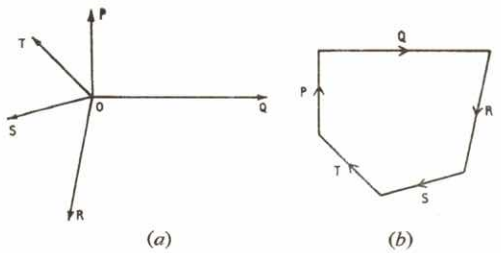


Fig. 1

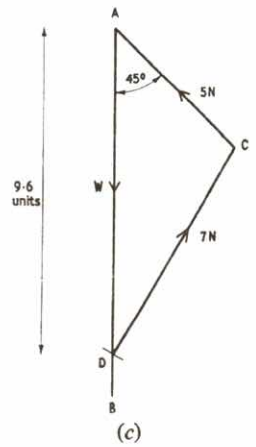
A body is supported by two forces as shown in Fig. 1. *Find the weight of the body and the angle made with the vertical by the 7-newton force.*

A. 1. The principle of the polygon of forces states that if any number of forces acting at a point can be represented in magnitude and direction by the sides of a polygon taken in order, the forces will be in equilibrium. This principle can be applied to decide whether a number of forces of known magnitude and direction are in equilibrium. The method is illustrated in sketches (*a*) and (*b*). Five forces acting at point O are represented in magnitude and direction by the vectors P, Q, R, S and T in sketch (*a*). These vectors are joined end to end as shown in sketch (*b*), where they form a closed polygon. Thus the five forces acting at point O are in equilibrium.

The two supporting forces and the weight of the body form a system of three forces in equilibrium and these can be represented by the three sides of a triangle, a special case of the polygon of forces, as shown in sketch (*c*).



(*a*) (*b*)



(*c*)

The triangle of forces is constructed as follows. AB is drawn to represent the direction of the weight. AC is drawn to a suitable scale to represent the 5-newton force in both magnitude and direction. An

arc, representing the magnitude of the 7-newton force, is struck from C to cut AB at D. The resulting triangle ACD is the triangle of forces for the system and, by measurement, the weight is found to be 9·6 newtons and the angle between the 7-newton force and the vertical 30 degrees.

Q. **2.** *State the principle of moments. The uniform bar shown in Fig.* 2 *weighs* 10 *kg and is used to raise a load of* 100 *kg.*

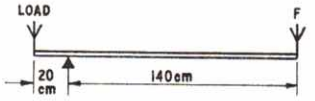


Fig. 2

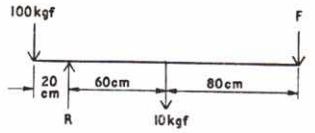
Find

(*a*) *the force F required to lift the load,*
(*b*) *the force exerted by the bar on the fulcrum,*
(*c*) *the shear force at the centre of the bar.*

A. 2. The principle of moments states:

If a body is at rest under the action of several forces, the total clockwise moment about any and every axis is equal to the counter-clockwise moment of the forces about the same axis.

(*a*) The forces acting on the bar are shown in the sketch. The



weight of the bar, being uniform, is assumed to act at the centre of the bar.

Equating moments about the fulcrum,

$$100 \times 20 = 10 \times 60 + F \times 140.$$

$$\therefore F = \frac{2{,}000 - 600}{140} = \underline{10 \text{ kgf.}}$$

(*b*) The force exerted by the bar on the fulcrum equals the sum of the downward forces, i.e. $100 + 10 + 10 = \underline{120 \text{ kgf.}}$

(*c*) The downward forces to the right of the centre of the bar are the force F and half the weight of the bar, i.e. $10 + 5$ kgf. For equilibrium, these equal the resultant of the forces to the left of the centre. Therefore, the shear force at the centre of the bar is 15 kgf.

Q. **3.** *Explain the terms kinetic energy, potential energy and power. Name one unit of energy and one of power.*

A water pump gives an output power of 1 *kW while being used to raise* 10,000 *kg of water through a vertical distance of* 20 *metres.*

Find, (*a*) *the time taken,* (*b*) *the input power to the pump, if the efficiency is* 80 *per cent.*

A. 3. *Kinetic energy* is the ability to do work possessed by a body by virtue of its motion. To slow down a moving mass a force must be applied in the opposite direction to the motion. In the process of slowing down, the moving mass moves the point of application of the retarding force, and hence does work on it, thus giving up energy as it slows down.

Potential energy is the ability to do work possessed by a body by virtue of its position or internal stress. For example, a raised weight can do work while it is falling under the force of gravity and a wound spring can also do work while unwinding.

Power is the rate of doing work and is measured in terms of the work done in a given time. Thus, the greater the power the greater the quantity of work that can be done in a given time or the shorter the time required to do a given amount of work.

In the m.k.s. system of units the units of energy and power are the joule and the watt, respectively.

(*a*) Work done = force × distance moved.

$\therefore$ work done in raising water = (10,000 × 9·81) newton × 20 metres,

$$= 1{\cdot}962 \times 10^6 \text{ joules.}$$

$$\text{Time taken} = \frac{\text{work done}}{\text{power applied}},$$

$$= \frac{1{\cdot}962 \times 10^6}{10^3} \text{ seconds}$$

$$= 1{,}962 \text{ seconds.}$$

$\therefore$ Time taken to raise water = $\underline{32 \text{ min } 42 \text{ sec.}}$

(*b*) $$\text{Efficiency} = \frac{\text{power out}}{\text{power in}}.$$

$$\therefore \text{Power input} = \frac{\text{power output}}{\text{efficiency}},$$

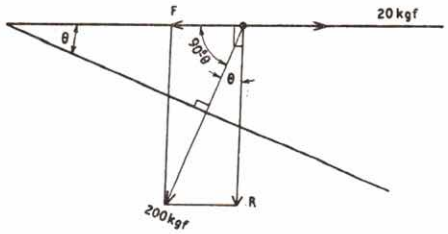
$$= 10^3 \times \frac{100}{80} \text{ watts,}$$

$$= \underline{1{\cdot}25 \text{ kw.}}$$

Q. **4.** *A force of* 20 *kgf is used to tow an empty trailer weighing* 200 *kg up an incline of one in twenty* (*i.e. unit rise in twenty units of slope distance*).

Find,

(*a*) *the components of the weight of the trailer* (*i*) *parallel to and* (*ii*) *perpendicular to the ground,*
(*b*) *the acceleration of the empty trailer,*
(*c*) *the maximum load which can be placed in the trailer and still allow the towing force to move it from rest.*



A. 4. The forces acting on the trailer are shown in the sketch. The weight of the trailer can be resolved into two rectangular components, the force acting down the slope, F, and the force at right angles to the slope, R.

(*a*) The angle between the weight and component R is the same as the angle between the incline and the horizontal.

$$\text{Therefore, } \frac{F}{200 \text{ kgf}} = \frac{1}{20}.$$

Therefore, the force parallel to the ground = $\underline{10 \text{ kgf.}}$

By Pythagoras' theorem,

$$R^2 + F^2 = (200 \text{ kgf})^2.$$

$$\therefore R = \sqrt{40{,}000 - 100}$$

$$= \sqrt{39{,}900.}$$

The force perpendicular to the ground = 199·7 kgf.

(*b*) The accelerating force = $20 - F$ kgf,

$$= 10 \text{ kgf.}$$

$$\text{Acceleration} = \frac{\text{force}}{\text{mass}},$$

$$= \frac{10 \times 9{\cdot}81}{200} \text{ m/s.}$$

Acceleration of empty trailer = $\underline{0{\cdot}491 \text{ m/s.}}$

(*c*) The maximum component of the loaded trailer parallel to the ground equals 20 kgf.

$$\therefore \frac{20 \text{ kgf}}{\text{max. weight}} = \frac{1}{20}.$$

$\therefore$ max. weight of trailer and load = 400 kgf.

$\therefore$ max. load = $\underline{200 \text{ kg.}}$

Q. **5.** *What is meant by the statement that a conductor does not obey Ohm's law?*

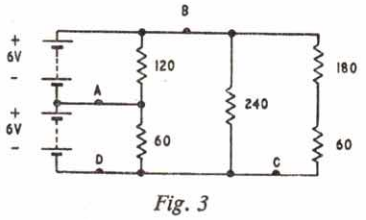


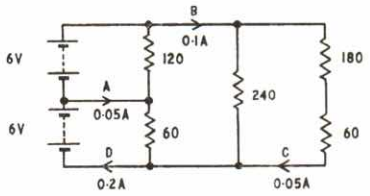
Fig. 3

Draw Fig. 3, *marking in the value and direction of the current at points A, B, C and D.*

In an effort to find a fault in this circuit, the following voltmeter readings were taken. What was the fault?

Voltage between A and D = 6 volts.
Voltage between B and C = 3 volts.

A. 5. Ohm's law states that at constant temperature, the potential difference between the ends of a conductor is proportional to the current flowing through it. Hence, when a conductor does not obey Ohm's law the p.d. across it is not proportional to the current through it even though the temperature is constant. Expressed in mathematical symbols the ratio $\frac{V}{I}$ is not a constant for a conductor that does not obey Ohm's law.



(*a*)

The required diagram with the directions and values of the currents marked is shown in sketch (*a*). The values of the currents are found as follows.

Current through C = current through 180-ohm + 60-ohm resistors in series,

$$= \frac{12}{240} = \underline{0{\cdot}05 \text{ amp.}}$$

Current through B = current through C plus current through 240-ohm resistor,

$$= 0{\cdot}05 + \frac{12}{240} \text{ amp.}$$

$$= \underline{0{\cdot}1 \text{ amp.}}$$

Current through D = current through B plus current through 60-ohm resistor,

$$= 0{\cdot}1 + \frac{6}{60} \text{ amp,}$$

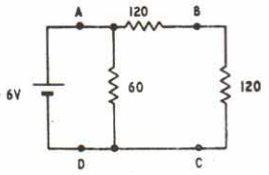
$$= \underline{0{\cdot}2 \text{ amp.}}$$

Current through A = current through 60-ohm resistor less the current through the 120-ohm resistor,

$$= \frac{6}{60} - \frac{6}{120} \text{ amp,}$$

$$= \underline{0{\cdot}05 \text{ amp.}}$$

The voltmeter readings on the faulty circuit are consistent with a disconnexion of the positive terminal of the upper battery. The circuit then simplifies to that shown in sketch (*b*), where half the battery



(*b*)

voltage is dropped across the 120-ohm resistor and the other half dropped across the 120-ohm effective resistance of the 240-ohm, 180-ohm and 60-ohm resistors.

***Q.* 6.** *Explain what is meant by the terms resistivity and conductivity. The winding space of a bobbin is filled with 20 metres of 0·093 cm diameter wire of copper with resistivity 1·60 × 10^{-8} ohm-metre. What is the resistance of the coil?*

If the same winding space were filled with wire of half the diameter, what would be the new resistance?

A. 6. The resistivity of a material is a measure of its ability to oppose the flow of a direct current through it. Unless otherwise qualified, resistivity is assumed to mean volume resistivity which is the resistance between two opposite faces of a unit cube of the material. In m.k.s. units the sides of the cube are one metre long and the unit of resistivity is the ohm-metre.

Conductivity is the inverse of resistivity, i.e. it is a measure of the ease with which a material will permit the flow of an electric current. The magnitude of the conductivity of a material is the reciprocal of its resistivity.

The resistance R of a wire is given by $R = \frac{\rho l}{a}$, where l is the length of the conductor, a is the cross-section area and ρ is the resistivity.

Substituting values,

$$R = \frac{1{\cdot}60 \times 10^{-8} \times 20}{\frac{\pi}{4} \times (0{\cdot}093 \times 10^{-2})^2},$$

$$= \frac{1{\cdot}60 \times 10^{-8} \times 20 \times 4}{\pi \times 8{\cdot}65 \times 10^{-7}},$$

$$\text{Coil resistance} = \underline{0{\cdot}471 \text{ ohm}}.$$

If the diameter of the wire is halved, the cross-section will be a quarter of its original area and approximately four times as many turns will be required to fill the same winding space.

$$\text{Hence } R' = \frac{\rho \times 4l}{\frac{1}{4}a}, \text{ where } R' \text{ is the new resistance,}$$

$$= 16R$$

$$\text{New coil resistance} = \underline{7{\cdot}54 \text{ ohms.}}$$

***Q.* 7.** *When a 57-ohm resistor is connected across a 200-volt supply, 10,000 calories of heat are generated in the resistor per minute. Calculate the mechanical equivalent of heat.*

If two 40-ohm resistors are available, how can they be used to draw from the 200-volt supply a power of

(*a*) $\frac{1}{2}$ *kW*, (*b*) 1 *kW*, (*c*) 2 *kW*.

A. 7. The heat dissipated in a resistor equals $\frac{V^2t}{R}$ joules, where V is the p.d. across it in volts, R the resistance in ohms and t the time in seconds. Therefore, heat generated in joules in one minute

$$= \frac{40{,}000}{57} \times 60,$$

$$= 42{,}100 \text{ joules.}$$

But, 10,000 calories are generated by the resistor in one minute. Therefore, 10,000 calories are equivalent to 42,100 joules, or, 1 calorie is equivalent to 4·21 joules.

Hence the mechanical equivalent of heat is $\underline{4{\cdot}21 \text{ joules/calorie.}}$

Power, P, dissipated in a resistance R is $= \frac{V^2}{R}$ watts.

$$\therefore R = \frac{V^2}{P} \text{ ohms.}$$

(*a*) When $P = \frac{1}{2}$ kW,

$$R = \frac{40{,}000}{500} \text{ ohms,}$$

$$= 80 \text{ ohms.}$$

Therefore, to supply $\frac{1}{2}$ kW, the $\underline{\text{two resistors must be connected in series.}}$

(*b*) When $P = 1$ kW,

$$R = \frac{40{,}000}{1{,}000} \text{ ohm,}$$

$$= 40 \text{ ohm.}$$

Therefore, to supply 1 kW, a $\underline{\text{single 40 ohm resistor is required.}}$

(*c*) When $P = 2$ kW,

$$R = \frac{40{,}000}{2{,}000} \text{ ohm,}$$

$$= 20 \text{ ohm.}$$

Therefore, to supply 2 kW $\underline{\text{the two resistors must be connected in parallel.}}$

***Q.* 8.** *What is meant by electrochemical equivalent? Write short notes on two chemical effects of a current which are of practical importance.*

A. 8. The electrochemical equivalent of a material is the mass of that material liberated by unit quantity of electricity. For example, the passage of 1 coulomb of electricity through a silver-nitrate solution will cause 0·0000011183 kgm of silver to be deposited at the cathode. Therefore, the electrochemical equivalent of silver is 1·1183 × 10^{-6} kgm/coulomb.

Two practical applications of the chemical effect of an electric current are electroplating and copper refining.

Electroplating. The object of electroplating is to give objects made

of one metal a coating of another metal in order to prevent corrosion or to improve their appearance. The object to be plated is made the cathode of an electrolytic cell, i.e. the electrode at which the current leaves the cell. Current enters the electrolyte via the anode which may be made of the plating material. The electrolyte is a suitable compound of the plating metal in solution. For chromium plating, for example, a lead anode is used, and the electrolyte is chromium-trioxide dissolved in water. To ensure an even coating the object being plated is surrounded by the anode (or anodes) and sometimes the cathode is slowly revolved for the same purpose.

The mass of metal deposited during electroplating is proportional to the quantity of electricity passed through the cell and, therefore, the rate at which it is deposited is proportional to the current flowing. If the current is too high the plating will not be sufficiently hard and adherent.

Copper refining. To obtain copper of sufficient purity for electrical work, copper ingots derived from smelting processes can be refined by electrolysis. The impure copper is made the anode of an electrolytic cell and thin, pure copper-plates are used for the cathode. The electrolyte is copper-sulphate solution. When current is passed through the electrolyte, copper is deposited at the cathode from the electrolyte and copper from the anode is converted to copper-sulphate and goes into solution to replace it. The impurities, however, do not go into solution in the electrolyte, but fall to form a sludge at the bottom of the cell. This sludge contains a fair proportion of gold and silver which can be profitably extracted by other electrolytic processes.

***Q.* 9.** *State Lenz's law of electromagnetic induction.*

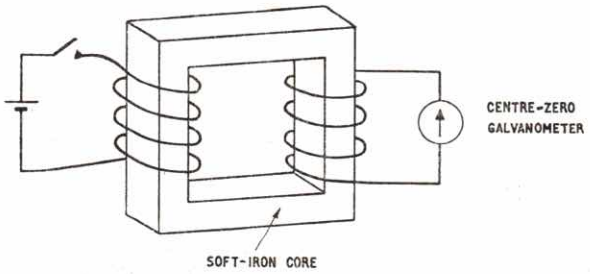
Why may arcing occur between the contacts of a switch used to break the current in a low-voltage circuit containing an electromagnet?

With the aid of diagrams, describe how mutual inductance can be demonstrated.

A. 9. Lenz's law of electromagnetic induction states that the direction of an electromagnetically-induced e.m.f. is such as to produce, or tend to produce, a current that will oppose the motion or change of flux giving rise to it.

When a current flows in the winding of an electromagnet, the magnetic flux produced links with the turns of the winding. Disconnexion of the current causes a collapse of the magnetic flux and hence a change in flux linkages, which in turn causes an e.m.f. to be induced in the electromagnet. This e.m.f. will appear in series with the original voltage source across the contact breaking the circuit. The magnitude of the induced e.m.f. is proportional to the rate of change of flux linkages and if this is high the e.m.f. appearing across the breaking contact will also be high and may be sufficient to cause sparking at the breaking contact even though the supply voltage is low.

A method of demonstrating mutual inductance is illustrated in the sketch. Two separate windings of insulated wire are wound on a



core of soft iron. One winding is connected to a centre-zero galvanometer and the other winding is connected via a switch to a battery. Initially there will be no reading on the galvanometer. If the switch is closed and kept closed, there will be a momentary deflexion of the galvanometer needle. When the switch is opened there will be another momentary deflexion of the needle, but this time in the opposite direction. The momentary deflexions during the opening and closing of the switch indicate that mutual inductance exists between the two windings. The act of opening and closing the switch causes a change in the current flowing in the associated winding; closing the switch causes the current to rise from zero to some steady value, opening it causes the current to fall from its steady value to zero. At the instant that the switch is opened or closed, i.e. at the instant the current is changing, e.m.f.s are induced into the other winding as is indicated by the deflexion of the galvanometer. Thus, the changing current in one winding induces an e.m.f. in the other winding and mutual inductance must exist between the two windings.

***Q.* 10.** *Show how a meter having a full-scale deflexion of* 1 *mA and a resistance of* 50 *ohms may be adapted for use as,*

(*a*) *a meter with full-scale deflexion of* 1 *amp,*
(*b*) *a voltmeter with full-scale deflexion of* 1 *volt.*

A simple ohmmeter is constructed by connecting the 1-*mA meter in series with a* 1·5-*volt cell and a resistor R as shown in Fig.* 4. *R is*

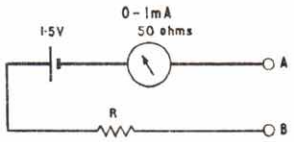
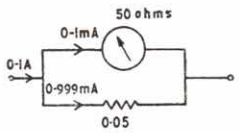


Fig. 4

chosen so that full-scale deflexion is obtained when the terminals A and B are shorted. Find the value of R. What is the value of resistance which, when connected between A and B, causes a reading of 0·65 *mA?*

A. 10. (*a*) The meter can be adapted to give a full-scale deflexion for 1 amp by the connexion of a shunt as shown in sketch (*a*). When



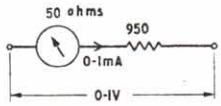
(*a*)

measuring a current of 1 amp, the current through the meter movement is 1 mA and the other 999 mA flow through the shunt.

The p.d. across the movement, $V = 1\text{ mA} \times 50\text{ ohms}$
$= 50\text{ mV}.$

The resistance of the shunt $= \dfrac{50\text{ mV}}{999\text{ mA}}$
$= 0{\cdot}05\text{ ohm}.$

(*b*) The meter can be adapted to give a full-scale deflexion for 1 volt by the connexion of a resistor in series as shown in sketch (*b*).



(*b*)

The current through the meter movement for full-scale deflexion is 1 mA.

Total circuit resistance for 1 volt $= \dfrac{1\text{ volt}}{1\text{ mA}} = 1{,}000\text{ ohms}.$

$\therefore$ the resistance of the series resistor $= 1{,}000 - 50\text{ ohm} = 950\text{ ohms}.$

The circuit current when A and B are short circuited is 1 mA.

$$\therefore \text{ total circuit resistance} = \frac{1{\cdot}5\text{ volt}}{1\text{ mA}} = 1{,}500\text{ ohms}$$

$$\therefore R = 1{,}500 - 50 = \underline{1{,}450\text{ ohms.}}$$

When the circuit current $= 0{\cdot}65$ mA,

$$\text{total circuit resistance} = \frac{1{\cdot}5}{0{\cdot}65} = 2{\cdot}31\text{ kohms}$$

$\therefore$ resistance between A and B $= 2{,}310 - 1{,}500$ ohms
$= \underline{810\text{ ohms.}}$

ENGINEERING DRAWING, 1968

Students were expected to attempt *Q.* 1 and not more than any three questions from *Q.* 2—6.

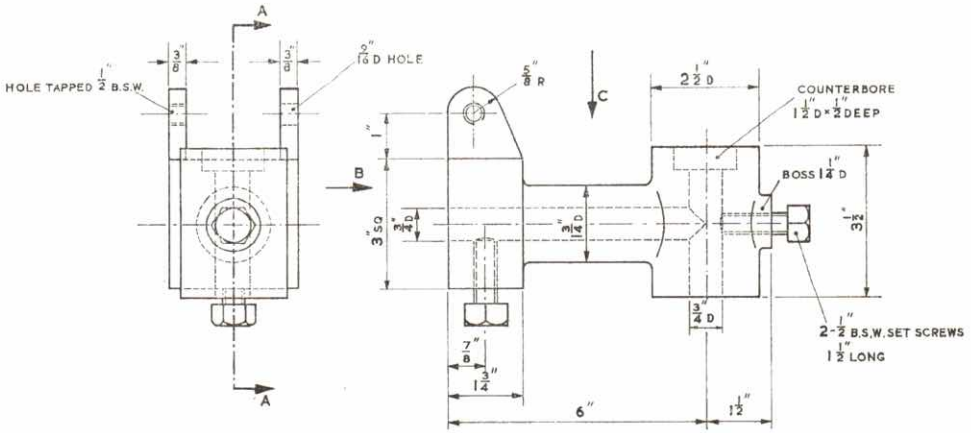


Fig. 1

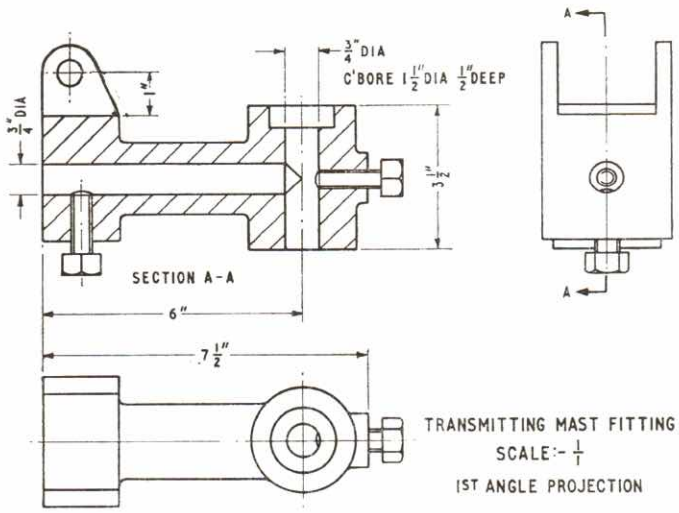
Q. 1. *Two elevations of a transmitting mast fitting are shown in first angle projection in Fig.* 1.

Draw FULL SIZE in either FIRST or THIRD ANGLE projection the following three views:

(a) a sectional elevation on AA,
(b) an elevation, projected from (a) in the direction of arrow B,
(c) a plan view, also projected from (a), in the direction of arrow C.

Add to your drawing six important dimensions, a title and scale and state which projection system you have used.

A. 1. The required views are shown in the sketch. For convenience in printing, the sketch is reproduced at a reduced size from that asked for in the question.



Q. 2. *The points A, B and C are located as shown in Fig.* 2. *Draw a circle to pass through each of these points and draw two tangents to the circle, each passing through point O.*

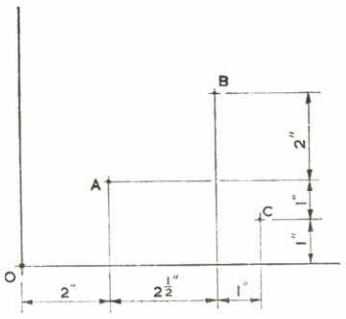
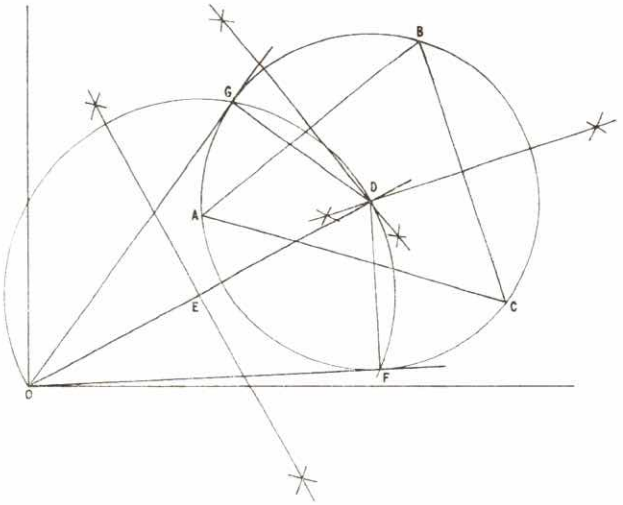


Fig. 2

ALL UNSPECIFIED RADII 1/8"

A. 2. The required drawing is shown in the sketch and the constructions are described.

Locate points A, B and C. Bisect lines BA and BC intersecting at D. From D draw the circumscribed circle. Join O and D and bisect



OD at E. From E draw the arc OF. Draw lines DG and DF, then G and F are points of tangency for lines OG and OF. Draw these lines at right angles to DG and DF.

Q. 3. *An oblique cone is shown in Fig.* 3. *This cone is cut by the plane XX. Draw, full size, the development of half of the sloping surface marked Y.*

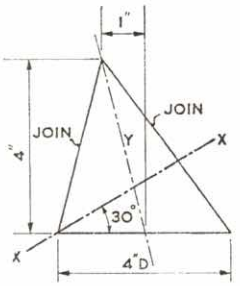
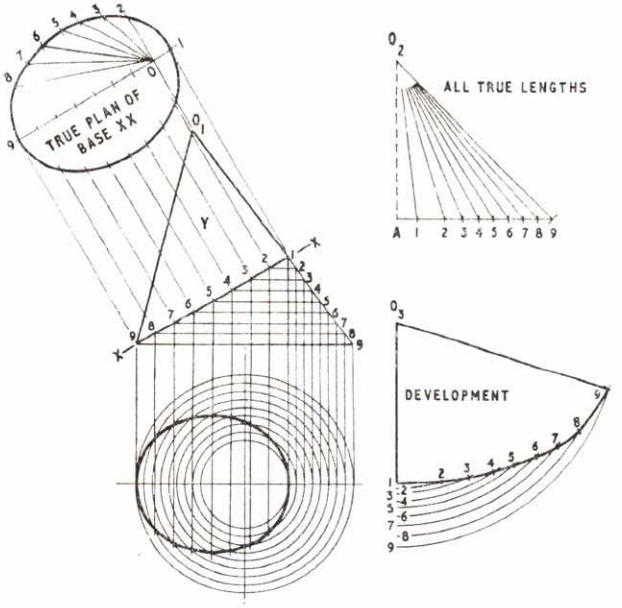


Fig. 3

A. 3. The required views are shown in the sketch at a reduced size. Although not asked for in the question, the constructions are described.

Draw the plan and elevation of the cone and draw the section plane XX. Divide this line into any number of parts, say eight, and through these divisions draw lines across the elevation parallel to base 99, cutting the side in 22, 33, 44, etc. From the intersections on the side, draw verticals to cut the centre line on the plan and draw circles from



these points. Draw vertical projectors from the intersections on plane XX, cutting the circles. The intersections of the projectors and the circles give points on the ellipse. Join these points to complete the plan view.

To obtain the true shape of the face XX, construct the figure in the plane shown, and, taking lengths from the ellipse in the plan, mark off points to complete the ellipse which is now the elliptical base XX of the cone it is required to develop. Project the apex O_1 of the cone to the true plan at O and draw lines O_1, O_2, O_3, etc. These lines are the true base lengths of the individual triangles.

Draw O_2A equal to the vertical height of the cone, O_29 equal to O_19. Draw A9 and arcs A8, A7, A6 etc. equal to lengths O8, O7, O6 etc. in the true plan of base XX. Connect these points to O_2, thereby obtaining the true length of the hypotenuse of each triangle.

Fix point O_3 and from this point draw arcs in the development equal to O_29, O_28, O_27 etc., then mark off arcs 12, 23, 34 etc. taken from 12, 23, 34 in the true plan of base XX to arcs in the development. Connect these points with a smooth curve and draw O_39 and O_31 to give the development of half the sloping surface, marked Y in the question.

***Q.* 4.** *Fig.* 4 *shows two views of a solid. Draw, full size, an isometric view of the solid. The corner P should be at the lowest point of your drawing. Hidden detail need not be shown.*

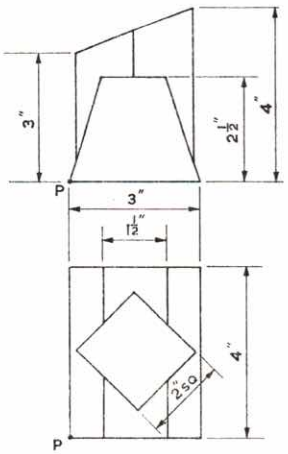
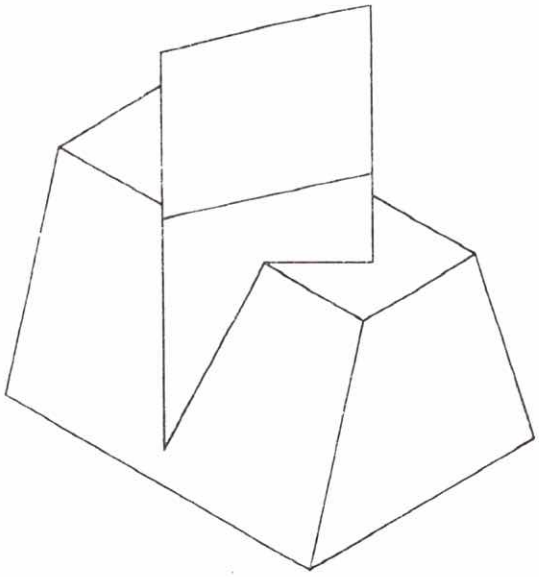


Fig. 4



A. 4. The isometric drawing is shown in the above sketch. For convenience in printing, the sketch is reproduced at a reduced size from that asked for in the question.

***Q.* 5.** *Specify suitable materials for the following and give reasons for your choice:*

(*a*) *the positive and negative poles of a dry cell,*
(*b*) *a small permanent magnet,*
(*c*) *the main structure of a transmitting mast.*

A. 5. (*a*) The positive pole should be carbon and the negative pole zinc. These materials are cheap and good electrical conductors and, with a suitable electrolyte, an e.m.f. of about 1·5 volts is developed due to chemical action between these materials.

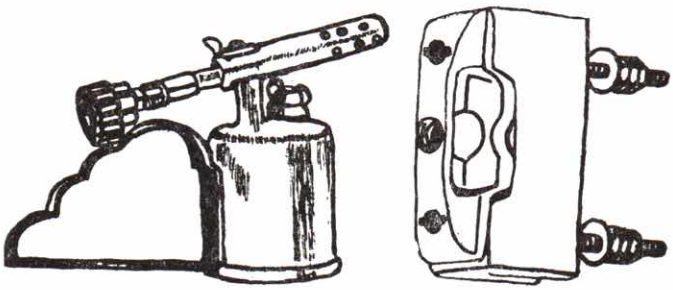
(*b*) Tungsten steel is used widely for permanent magnets because of its very high magnetic retentivity.

(*c*) Mild steel is a suitable material because:

(*i*) it has a high tensile strength,
(*ii*) it is easily machined,
(*iii*) it is cheap, and
(*iv*) it is ductile, a property which allows a considerable amount of deformation before fracture occurs, thereby enabling the mast to withstand wind pressures without collapsing.

***Q.* 6.** *Make a neat, free-hand sketch of either* (*a*) *a type of blow lamp or* (*b*) *a switch-board fuse.*

A. 6. The free-hand drawings are shown in the sketches.

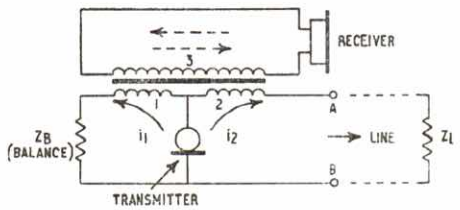


TELEPHONY AND TELEGRAPHY A, 1968

Students were expected to answer any six questions.

***Q.* 1.** *What is the cause of side-tone in a subscriber's telephone? Describe with the aid of sketches any simple means of reducing side-tone in a telephone circuit. Why is the reduction of side-tone considered desirable?*

A. 1. A telephone is designed to work on a two-wire line, therefore the transmitter and receiver must both be connected or coupled to the two wires. This means that changes in current produced by the transmitter when dealing with outgoing speech will be reproduced in



the receiver of the same telephone. This effect is known as side-tone.

A simple means of reducing side-tone in a telephone circuit is shown in the sketch. When the transmitter is being influenced by outgoing speech, its resistance will vary and cause currents flowing in windings 1 and 2 of the induction coil to vary. The directions of the currents are shown in the sketch by arrows designated i_1 and i_2. The direction and turns ratio of the induction-coil windings are arranged so that the induced voltages across winding 3 are equal and opposite. The receiver connected in series with winding 3 is then subjected to two equal and opposite alternating voltages, hence no current flows in the receiver.

When the telephone is receiving speech from line, the currents flowing through windings 1 and 2 are in the same direction and the two e.m.f.'s induced into winding 3 are additive; thus the arrangement has no adverse effect on signals received from the line.

The reduction of side-tone is necessary because side-tone reduces the overall efficiency of the telephone as follows:

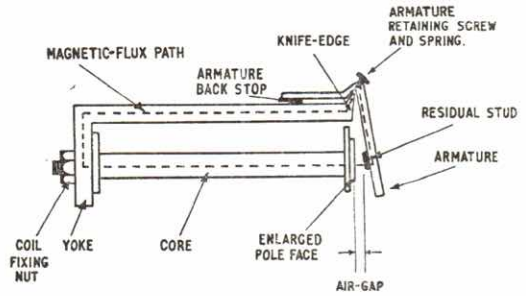
(*a*) It lowers the transmitting efficiency because power is wasted in the receiver circuit; and a high level of side-tone causes the speaker to lower his voice thus reducing the signal to line.

(*b*) It affects the receiving efficiency by producing ear fatigue, and room noises picked up by the transmitter tend to mask the received speech.

***Q.* 2.** *Sketch the magnetic circuit of a general-purpose telephone relay and describe its important features.*

What are the desirable properties of the materials used for the component parts of the magnetic circuit? Why is magnetic remanence an undesirable property for the core material?

A. 2. The magnetic circuit of a general-purpose telephone relay is shown in the sketch. The important features of the magnetic circuit are the low reluctance path to the magnetic flux and the controlled air gaps. The low reluctance path is provided by the core, yoke, armature knife-edge, and the armature. Special attention is given to the close-fitting joint between the core and yoke and the armature-knife-edge and armature to keep the reluctance at these points to a minimum.



The armature back-stop and residual stud or screw provide a controlled air gap between the armature and the core pole-face, and prevent a closed magnetic circuit. The armature-retaining screw and spring hold the armature firmly on the knife-edge thus ensuring a good pivot, but at the same time keeping the reluctance at the joint as low as possible.

Two materials are used for the component parts of the magnetic circuit. The armature, yoke, core and pole face are made of a good quality annealed soft-iron, as this material is malleable, has a high permeability and low retentivity. The residual stud or screw and the armature back-stop are made of phosphor bronze, which is a relatively hard non-magnetic metal and will withstand impact without excessive deformation. In some modern relays the armature back-stop is made of Keramot, but any hard non-magnetic material would suffice.

Magnetic remanence is undesirable in a general-purpose relay because it would decrease the operate-time and increase the release-time of the relay and could, in an extreme case, prevent the relay from releasing when the current to the coil is disconnected.

***Q.* 3.** *What is the difference between the Morse code and the five-unit code? Why is the latter chosen for teleprinter working?*

Sketch simplified circuit arrangements for sending and receiving teleprinter signals using the five-unit code. Sketch the line current signals transmitted for a single character; assume a rectilinear waveform.

A. 3. In the Morse code each letter of the alphabet and each numeral is represented by discrete combinations of two basic signals, dots and dashes, which differ only in their duration; a dash being three times the duration of a dot. As it is necessary to distinguish between elements of a character, between characters, and between words, time intervals are allocated as follows:

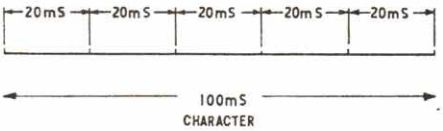
(*a*) Between elements of a character—1 time unit,
(*b*) Between characters—3 time units,
(*c*) Between words—7 time units,

where one time unit equals the duration of a dot.

(*a*)

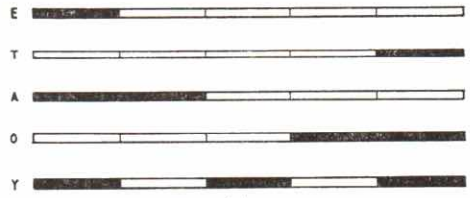
Sketch (*a*) illustrates the different transmission time for various characters.

In the five-unit telegraph code each character consists of a discrete combination of five elements of equal duration. All five elements are used for every character and an appropriate signal condition is used to "mark" or "not mark" the particular section of the complete character.



(*b*)

Sketch (*b*) shows the structure of the five unit code on a teleprinter working at a speed of 50 bauds. Sketch (*c*) shows the uniform transmission time for the same five characters shown in morse code in Sketch (*a*). The two state five-unit code will give $2^5 = 32$ combinations, and when used for teleprinter working two character combinations are used for letter/figure shift, and this increases the number of working characters to 62. To differentiate between successive characters, and to facilitate synchronization between the sending and receiving machines, each character is prefixed with a 20 mS start signal and suffixed with a 30 mS stop signal.



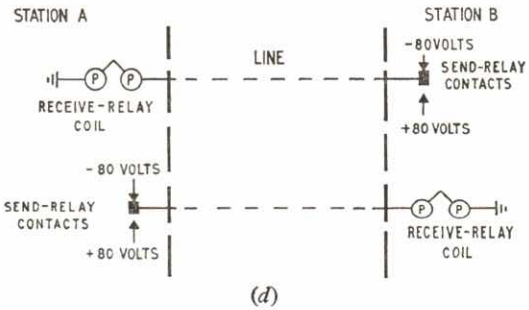
(*c*)

The five-unit code is used for teleprinter working for the following reasons:

(*a*) The number of character combinations is sufficient for teleprinter working (62 working characters).

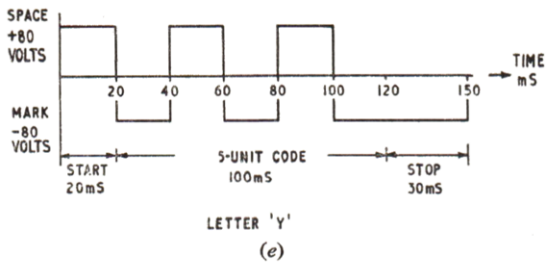
(*b*) All characters are composed of the same number of signal elements. This simplifies the mechanism for sending, receiving and direct printing.

(*c*) The uniform transmission time of all characters provides a simple basis for synchronization.



(*d*)

Sketch (*d*) shows the basic circuit arrangement for a simplex telegraph circuit. The send-relay contacts are shown in the idle-circuit



(*e*)

state, i.e. after the transmission of the "stop" signal from the previous message. Sketch (*e*) shows the line signals when transmitting the letter Y in the five-unit code. The sketch also shows the 20 mS start and 30 mS stop signals which form part of the teleprinter code.

EDITORIAL NOTE

Telephony and Telegraphy A *Model Answer Book*, 1967 contains an error in the answer to question 23. (*a*), (*b*) and (*c*) should read 1, 3 and 7 unit times.

Prior to 1949 the interval between words in the morse code was 5 unit times and this was changed to 7 units by international agreement. Text books written before this date therefore show the pre-1949 figure.

***Q.* 4.** *In the busy-hour at an exchange A,* 450 *subscribers each dial one call to another subscriber at A, while* 150 *take into use a junction to call subscribers at an adjacent exchange B. If the local calls have an average duration of* 3 *min, how much traffic do the* 450 *subscribers originate? If the junction traffic is* 5 *erlangs what is the average duration of a junction call?*

Explain why the number of junctions from A to B is in excess of 5 *but much less than* 150.

A. 4. The traffic flow is given by the formula $A = CT$. Where A is the traffic in erlangs, C is the total calls originated during the hour and T the average holding time of a call in hours.

450 subscribers make local calls with an average duration of 3 min or 1/20 hour.

$$A = 450 \times \frac{1}{20} = \frac{45}{2} = 22{\cdot}5 \text{ erlangs.}$$

$\therefore$ Local traffic is 22·5 erlangs.

150 subscribers make junction calls and the junction traffic is 5 erlangs.

$$T = \frac{A}{C}.$$

$$\therefore\ T = \frac{5}{150} = \frac{1}{30} \text{ hours} = \frac{1}{30} \times 60 = 2 \text{ min.}$$

$\therefore$ Average duration of a junction call is two minutes.

There are 150 junction calls made during the busy hour, the *average* duration of each call is 2 minutes and the total junction traffic during the busy hour is 5 erlangs.

If the calls were evenly distributed over the busy hour such that each new call originated at the instant that an existing call terminated, then 5 junctions would suffice. Since subscribers originate calls at any time, there will be periods when more than 5 simultaneous calls are required and hence more than 5 junctions must be provided in order to provide a good grade of service. On the other hand, it is unreasonable to cater for all 150 calls being made during the same two-minute period in the busy hour. In a typical case, 11 junctions would be needed to carry the 5 erlangs of junction traffic at a grade of service of one lost call in 100 with a selector availability of 20.

***Q.* 5.** *The traffic flow from level two of* 16 *shelves of* 200*-outlet* 1*st-numerical selectors is such that access must be given to* 40 2*nd-numerical selectors. Explain how the shelves should be formed into grading groups, and sketch a suitable grading.*

Explain how to determine the best arrangement of commoning between the grading groups.

A. 5. Modern graded-group selector racks accommodate 8 shelves of selectors with 10 selectors per shelf. Banks are factory wired in pairs of shelves (20 banks per preformed multiple), and these are terminated on blocks on the rear of the rack. Tie cables are provided to the adjacent racks and these are terminated on the same block. Commoning of shelves within the rack, or with an adjacent rack, is achieved by strapping on these blocks.

In the question, the 16 shelves of selectors will require two racks to accommodate them.

The number of grading groups is given by the formula:

$$\text{No. of groups} = \frac{2N}{A},$$

where N is the number of trunks and A is the availability.

In this example $N = 40$ and $A = 20$.

$$\therefore \text{ No of groups} = \frac{2 \times 40}{20} = 4.$$

In a four group grading, to preserve unformity, there will be singles, pairs and full commons. Let a be the number of singles, b the number of pairs and c the number of full commons,

$$\text{then, } 4a + 2b + c = 40, \quad (1)$$

$$\text{and, } a + b + c = 20. \quad (2)$$

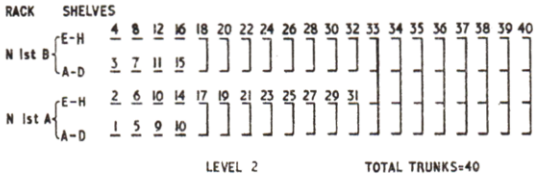
Subtracting (2) from (1), $3a + b = 20$

Substituting various values for a, the following table shows the corresponding values for b and c.

TABLE 1

a	1	2	3	4	5	6
b	17	14	11	8	5	2
c	2	4	6	8	10	12
Sum of successive differences	31	22	13	4	5	14

The best grading arrangement is the one in which there is a smooth progression from singles through to full commons, i.e. where the sum of the successive differences is least. In this example the preferred grading is: 4 singles, 8 pairs and 8 full commons.



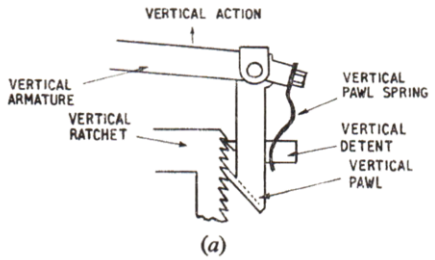
The sketch shows such a grading for the 16 shelves of group selectors.

***Q.* 6.** *In a two-motion selector the wipers are raised in steps to the required level by the vertical magnet and then rotated in steps by the rotary magnet. Sketch and describe the mechanical arrangements that prevent the wipers falling back to the rest position during vertical and rotary stepping.*

Explain how the wipers are returned to the rest position at the conclusion of a call.

A. 6. There are several types of two-motion selector, the most widely used is known as the 2,000-type selector and the question is answered in terms of this selector mechanism.

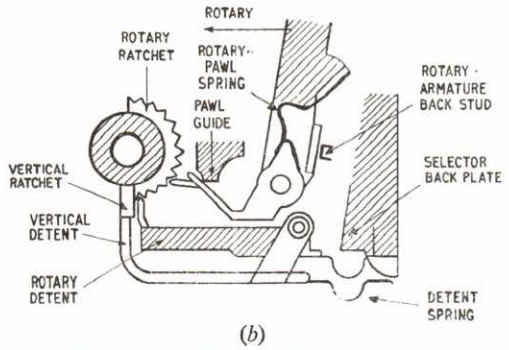
The elements of the vertical stepping mechanism of a 2,000-type



(*a*)

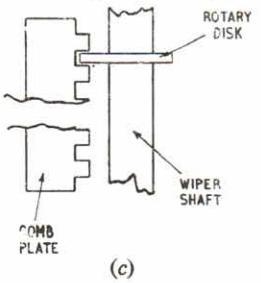
selector are shown in sketch (*a*). When the vertical magnet is energized the armature is attracted, and the pawl, under control of the pawl-spring, lifts the vertical ratchet and wiper carriage one step. At the end of each vertical step the detent, which is tensioned against the vertical ratchet by a spring shown in sketch (*b*), engages in a tooth in the ratchet. When the magnet is de-energized and the armature restores to normal, the wiper carriage is supported by the vertical detent. This action takes place for each vertical step of the mechanism.

The rotary stepping arrangements are shown in sketch (*b*). The operation is similar to that for vertical stepping, operation of the rotary armature causing the rotary pawl to move the rotary ratchet one step, while the rotary detent prevents the wiper carriage restoring to normal during rotary stepping.



(*b*)

During the first rotary step the vertical ratchet leaves the rotary detent, see sketch (*b*), but at the same time the rotary disk enters the appropriate notch in the comb plate and supports the wiper carriage.

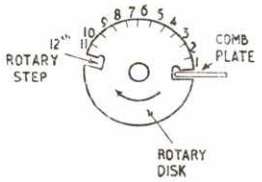


(*c*)

The comb plate and disk arrangement is shown in sketch (*c*) and it is this which prevents the wiper carriage falling after the first and subsequent rotary steps.

Thus, during a call, the wiper carriage is prevented from restoring to normal by the rotary detent and the rotary disk and comb plate.

At the conclusion of a call, the rotary magnet is re-energized in series with the interrupter springs, and the wiper carriage is driven to the 12th rotary position. In this position the wipers are clear of the bank



(*d*)

and a slot in the rotary disk clears the comb plate, see sketch (*d*). The wiper carriage drops to the normal level due to gravity and the tension of the extended restoring spring located within the wiper shaft. At the normal level the rotary ratchet is clear of the rotary detent and the wiper carriage restores to the normal position due to the tension imparted to the restoring spring during the rotary action.

***Q.* 7.** *Explain the functions of a main distribution frame in an automatic exchange.*

Determine the approximate floor space required for an m.d.f. at a 10,000-*line exchange.*

What advantages and disadvantages do you see in having a smaller m.d.f. in which the line and multiple terminations are more densely packed.

A. 7. The main distribution frame (m.d.f.) in an automatic telephone exchange is the point at which street cables are terminated and connected to the exchange equipment. It provides a flexibility point at which cables arriving in geographical order may be cross-connected to any equipment position within the exchange, or to another local or junction cable to form through-circuits. It is a convenient point at which to provide protection in the form of fuses and lightning arrestors, testing access for circuit maintenance, and the introduction of special facilities such as service interception, transfer service, and the temporary disconnexion of service. In addition to the requirement to terminate a cable pair for each working exchange line, m.d.f. accommodation is required for spare pairs in subscribers' cables to allow for exchange growth and the movement of customers from one part of the exchange area to another. Provision must also be made to terminate incoming and outgoing junction-cable pairs, and pairs for private and other through-circuits.

In general, the size of an m.d.f. is determined by the requirements on the line-side, and experience has shown that if the actual number of pairs required for working subscribers' lines is multiplied by 1·6, this gives a reasonable estimate of the total number of pairs to be terminated.

In this example there would be 10,000 × 1·6 = 16,000 cable pairs to terminate.

The modern m.d.f. has verticals approximately 7 in apart, each vertical accommodates 10 mountings and each mounting provides terminating space for 40 cable pairs or circuits.

The number of verticals required, therefore $= \dfrac{16{,}000}{10 \times 40} = 40$

The overall length of the frame will be $40 \times \dfrac{7}{12} = 24$ ft.

The approximate width of the frame is 4 ft, therefore the floor area for the frame itself is 24 × 4 = 96 ft². In a telephone exchange a gangway of at least 4 ft is provided around the frame, thus the total floor area required for the m.d.f. and the access to it is 384 ft².

The advantages of a smaller m.d.f. are as follows:

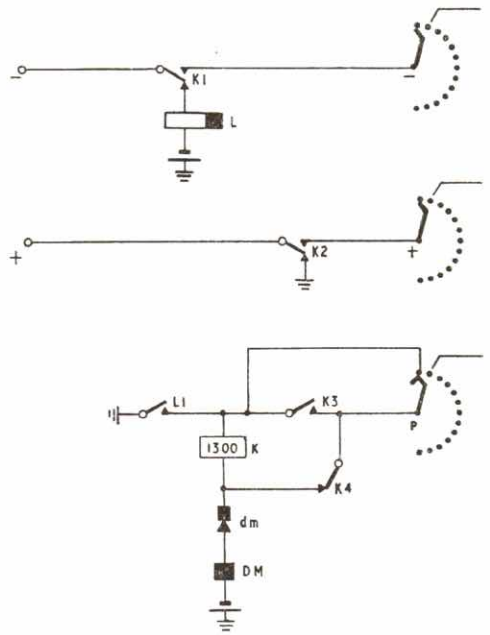
(*a*) saving in floor space,
(*b*) saving in amount of cable and jumper wire used,
(*c*) reduction in walking distances.

The disadvantages are as follows:

(*a*) congestion in the jumper field, hence difficulty in providing, recovering and tracing jumpers,
(*b*) closer spacing of fuses, tags and lightning protectors may make jumpering more difficult,
(*c*) closer spacing may increase the number of faults on blocks, etc.

***Q.* 8.** *Sketch the circuit element of a uniselector hunter that, on receipt of a start signal, will search for and seize a disengaged trunk. Describe the circuit operation during hunting and explain how the trunk which is seized is quickly busied against intrusion by other subscribers.*

A. 8. The sketch shows the circuit element of an earth testing uniselector.



When the circuit is seized, the loop on the incoming positive and negative wires operates the L relay. Contact L1, in operating, connects earth to the K relay coil and, via the normal position of the P-wire uniselector arc, contact K4 and the uniselector dm springs, energizes the uniselector drive magnet. K relay will not operate due to the earth on both sides of its coil. The uniselector magnet is operated by the earth at contact L1, and the dm springs open; the magnet is de-energized and the uniselector wipers step to contact 1. If the first outlet is engaged the earth present on the P-wire maintains the earth on the dm side of the K relay, thus preventing its operation. This earth re-operates the dm magnet and the uniselector takes another step and will continue to do so each time there is an earth on the P-wire outlet. When the uniselector outlet wipers step onto a free outlet (the free condition being indicated by a disconnexion on the P-wire) the absence of the earth removes the short-circuit from the K relay and it operates in series with the uniselector drive magnet, the current which flows being insufficient to operate the drive magnet. K relay operates and contact K3 prepares a hold-circuit for relay K to the P-wire. Contacts K1 and K2 extend the calling loop forward to the next switching stage; this operates the A relay in the selector or relay-set which, in turn, operates its associated B relay to return an earth on the P-wire to hold the K relay in the uniselector hunter circuit. The outlet which is seized is busied immediately by an earth which is extended via contacts L1 and K3 to the P-wire. On the release of the L relay, the outlet is maintained busy by the earth returned on the P-wire by the next selector or relay set.

If the uniselector was used as a subscriber's line circuit it would be necessary to maintain a busy condition on the P-wire of the final

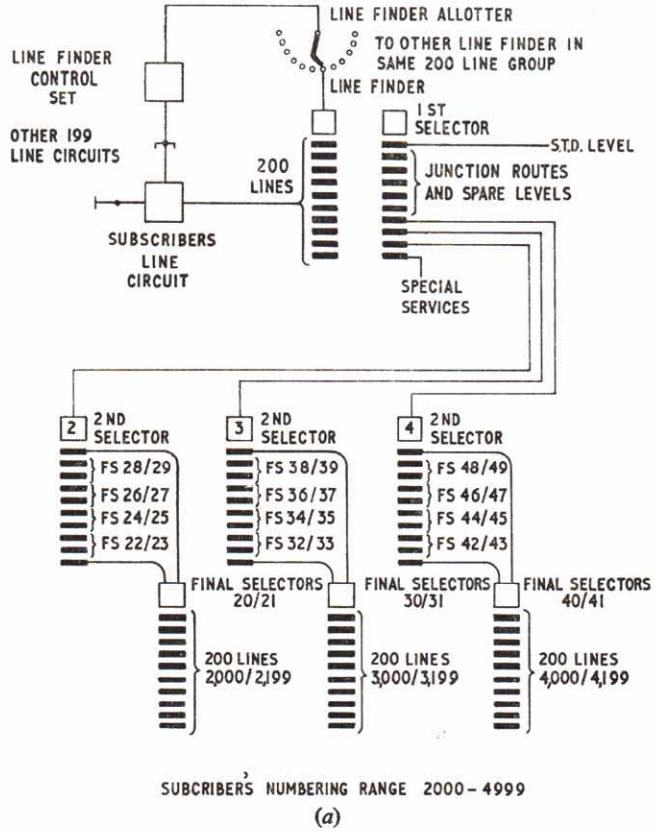
selector multiple from the instant the L relay operated until the uniselector restores to normal.

The design features of the circuit element shown in the sketch are as follows.

(*a*) Relay L is made slow to release to hold relay K and apply a forward holding earth to the P-wire during the operate lags of relays A and B in the subsequent switching stage.

(*b*) Bridging wipers are provided in the uniselector P-arc to ensure that the short circuit is maintained across the K relay whilst the uniselector is stepping between earthed outlets.

***Q.* 9.** *Sketch a trunking diagram of a 3,000-line automatic exchange to show the routing of calls to local subscribers; assume the use of 200-point line-finders and 200-outlet final selectors.*



(*a*)

A 1st-numerical selector is found to be seized but not in use on a call, and it is suspected that this is due to the subscriber's line having developed a short-circuit fault. Explain how you would locate the suspected cable pair at the m.d.f.

A. 9. Sketch (*a*) shows the trunking arrangement of the 3,000-line automatic exchange employing 200-point line finders and 200-outlet final selectors.

In a 200-point linefinder system each linefinder accommodates 200 subscribers' lines and it is permanently cabled to a first selector. In this example the PG lamp indication is given on the first selector and this carries a label indicating its associated linefinder.

Inspection of the linefinder will indicate the level and outlet on which its wipers are positioned and reference to the linefinder record card for this 200-line group will give the directory number of the subscriber connected to the particular level and outlet of the group.

The subscribers' fault cards are filed in directory number order and reference to the fault card for this subscriber will give the m.d.f. cable pair.

***Q.* 10.** *Compare the merits of rectifier-type and motor-generator-type power plants for serving large automatic exchanges. Why is a step-down transformer required with rectifier plant but not with motor-generator-plant?*

A. 10. The advantages of a mains-operated rectifier-set over a mains-operated motor-generator-set are as follows:

(*a*) the initial cost of the rectifier is considerably less,

(*b*) the rectifier requires less floor space,

(*c*) the rectifier has an efficiency of 90 per cent compared with 70 per cent for the motor-generator set and is more economical to operate,

(*d*) the rectifier is noise and vibration free and can therefore be installed in normal exchange accommodation,

(*e*) the rectifier is a static device requiring no cleaning or lubricating thus the cost of maintenance is less than for the motor-generator,

(*f*) the absence of moving parts in the rectifier gives greater reliability in service.

Both rectifier and motor-generator sets are operated from the public mains supply, whilst the output voltage required to operate a telephone exchange is normally 50 volts. The step-down feature is thus essential in both systems. In motor-generator sets this is included in the motor-generator design, hence no external device is needed. In the rectifier sets, however, it is necessary to step down the voltage before rectification and this is achieved by the use of a step-down transformer.

RADIO AND LINE TRANSMISSION A, 1968

Students were expected to answer any six questions.

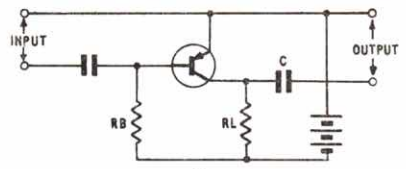
***Q.* 1.** *Explain the principle of operation of a resistance-loaded transistor amplifier in the common-emitter configuration.*

Draw the circuit diagram of a two-stage, resistor-capacitor coupled, audio-frequency amplifier in the common-emitter configuration.

Show clearly:

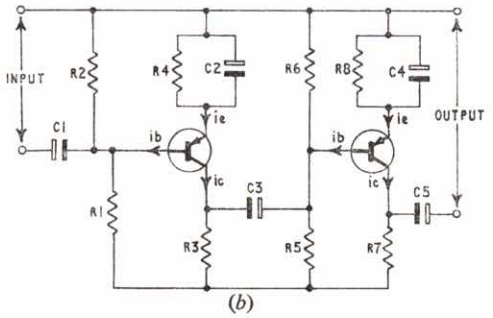
(*a*) *the biasing and stabilization arrangements,*
(*b*) *the directions of the currents flowing,*
(*c*) *suitable component values.*

A. 1. Sketch (*a*) shows a p–n–p, resistance-loaded, transistor amplifier in the common-emitter configuration. In this circuit the collector is



(*a*)

made a few volts negative with respect to the emitter and the base is biased a fraction of a volt negative with respect to the emitter, by means of resistor RB. Hence, the base-emitter junction is biased in the forward direction and the collector-base junction is biased in the reverse direction. It may be shown, from the output characteristics of a p–n–p transistor biased in this manner, that a small change in the base current (input circuit) causes a much larger change in the collector current (output circuit). The ratio of these two current changes is approximately of the order of 30–50 and represents a current gain. Using this current gain, the common-emitter amplifier can be shown to have a voltage and power gain.



(*b*)

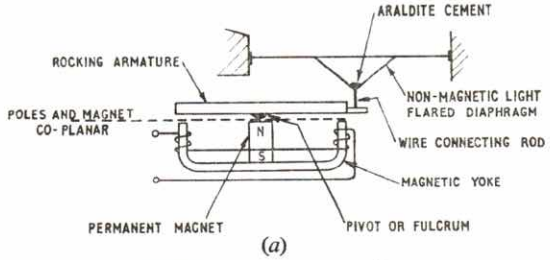
C1, C3, C5—10 μF
C2, C4—100 μF
R1—56 kohms
R2, R6—10 kohms
R3, R5—3·9 kohms
R4, R8—1·2 kohms

Sketch (*b*) shows the circuit diagram of a two-stage, RC-coupled, audio-frequency amplifier using transistors in the common-emitter arrangement. The directions of the currents flowing have been indicated, together with typical component values. The first stage is biased and d.c. stabilized by the potential divider resistors R1, R2 and the emitter resistor, R4. Resistors R5, R6 and R8 perform similar functions for the second stage.

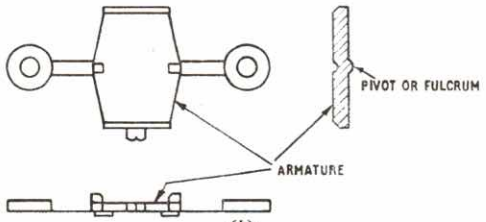
Q. 2. *Describe, with the aid of a sketch, the essential features of a modern, moving-iron, diaphragm telephone-receiver and explain its principle of operation.*

State why the moving-iron diaphragm-receiver is preferred to the moving-coil receiver in commercial telephone systems.

A. 2. The basic elements of the modern telephone receiver inset is shown in sketch (*a*), with details of the rocking armature and its mounting in sketch (*b*). This type of inset, known as the rocking armature receiver, derives its name from the fact that the armature



(*a*)



(*b*)

rocks, or pivots, on a fulcrum resting on the magnet. The magnetic assembly consists of a rectangular permanent magnet mounted centrally between the limbs of a U-shaped yoke of Permalloy-B, which forms the two pole-pieces. The yoke and the magnet are soldered together and the faces of the magnet and pole-pieces are machined to form a co-planar surface. The armature, which is also made of Permalloy-B, rocks or pivots on the central magnet with the end faces of the armature opposed to the two pole-pieces. The armature is shaped to provide the optimum magnetic path for the flux, combined with the minimum effective moving mass. The windings are wound round the pole pieces to provide a series aiding effect around the yoke and armature circuit. The controlling force is provided by the armature torsional stiffness, and the armature is stabilised for equal air-gaps at both pole-pieces under static conditions.

When a signal current flows through the coils, the armature is displaced towards either pole, depending upon the direction of the current. This movement of the armature is transmitted to a light, flared, trumpet-shaped, non-magnetic diaphragm which reproduces sounds corresponding to the variations in signal current produced at the microphone.

This type of telephone receiver has high sensitivity and a flat sensitivity/frequency response over the range 200–3,400 Hz.

The moving-iron and rocking armature receivers are preferred to the moving-coil receiver in commercial telephone systems because they are less expensive and more robust, while providing adequate frequency response for commercial speech.

Q. 3. *Explain how the variation of impedance of a tuned circuit with frequency near resonance may be used to provide selectivity in a radio-frequency amplifier.*

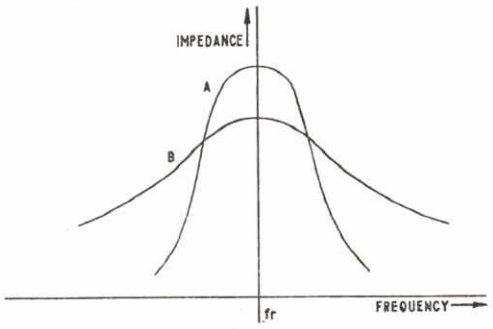
Table 1 shows the response of a parallel tuned circuit. Plot the voltage/frequency curve and use it to determine the response, in dB relative to the response at 200 kHz, to carrier signals centred on carrier frequencies of 195,185 and 175 kHz.

Frequency in kHz (kc/s)	170	180	190	194	196	198	200
Voltage	2	20	80	135	160	185	200

Frequency in kHz (kc/s)	202	204	206	210	220	230
Voltage	185	160	140	95	40	15

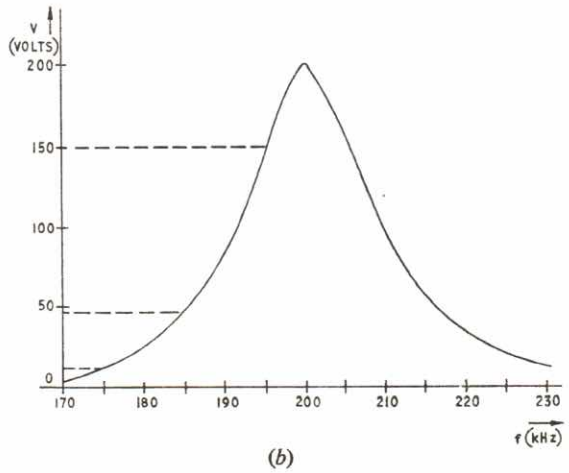
Table 1

A. 3. Two examples of the variation of impedance with frequency for a parallel-tuned LC circuit are shown in sketch (*a*). These curves show that the impedance of a parallel-tuned LC circuit is a maximum



(*a*)

at the frequency of resonance, f_r, and decreases in value on either side of f_r. This characteristic of a parallel-tuned LC circuit may be used in a radio-frequency amplifier to provide selectivity by connecting such a circuit as the anode-load in the radio-frequency amplifier. Since the voltage amplification factor of a radio-frequency amplifier is almost directly proportional to the value of its anode-load impedance, a desired signal at the resonant frequency of the tuned circuit will be amplified more than undesired signals received at frequencies off resonance. Further, this property of the tuned circuit, known as selectivity, is dependent upon the slope of the impedance/frequency curve, on either side of the resonant frequency. Thus, curve A is more selective than curve B.



(*b*)

The response curve referring to Table 1 is given in sketch (*b*).

From the graph:

(*i*) the response at 195 kHz = 150 volts.

$\therefore$ response at 195 kHz, relative to response at 200 kHz

$$= 20 \log \frac{150}{200} = 20 \log 0{\cdot}75$$

$$= 20 \times \bar{1}{\cdot}8751 = \underline{-2{\cdot}5\text{dB}}.$$

(*ii*) the response at 185 kHz = 45 volts.

$\therefore$ response at 185 kHz, relative to response at 200 kHz

$$= 20 \log \frac{45}{200} = 20 \log 0{\cdot}225$$

$$= 20 \times \bar{1}{\cdot}3522 = \underline{-13\text{dB}}.$$

(*iii*) the response at 175 kHz = 10 volts.

$\therefore$ response at 175 kHz, relative to response at 200 kHz

$$= 20 \log \frac{10}{200} = 20 \log 0{\cdot}05$$

$$= 20 \times \bar{2}{\cdot}699 = \underline{-26\text{dB}}.$$

Q. 4. *Sketch sets of curves showing the following valve and transistor characteristics:*

(*a*) *I_a against V_a for various values of V_g for a triode valve,*

(*b*) *I_a against V_g for various values of V_s (screen voltage) for a pentode valve,*

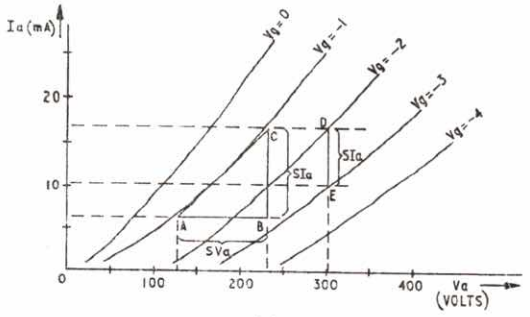
(*c*) *I_c against V_c for various values of I_b for a transistor in the common-emitter connexion.*

All axes should be clearly labelled with both units and signs.

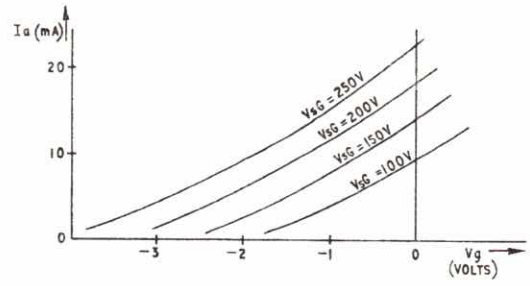
Use the curves in (a) to explain how the anode a.c. resistance and the mutual conductance of the triode valve may be determined.

Use the curve in (c) to explain how the output resistance and current gain of the transistor may be determined.

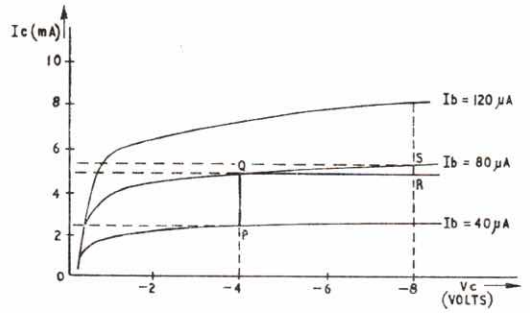
A. 4. The curves showing the required characteristics are given in sketches (*a*), (*b*) and (*c*).



(*a*)



(*b*)



(*c*)

The anode a.c. resistance of thermionic triode valve is the ratio of the change in anode voltage to the corresponding change in anode current with the grid voltage constant, i.e. $\frac{\delta V_a}{\delta I_a}$ with V_g constant.

With reference to the curves in sketch (*a*), the ratio $\frac{\delta V_a}{\delta I_a}$ is given by the inverse slope of the curves. Hence, for the curve $V_g = -1{\cdot}0$ volt, the anode a.c. resistance $= \frac{\delta V_a}{\delta I_a} = \frac{\text{AB}}{\text{BC}}$.

The mutual conductance of a thermionic triode valve is the ratio of the change in the anode current to the corresponding change in the grid voltage, with the anode voltage constant, i.e. $\frac{\delta I_a}{\delta V_g}$ with V_a constant.

The ratio $\frac{\delta I_a}{\delta V_g}$ is found by considering the change in I_a for a change in V_g from say -2 volts to -3 volts, with constant V_a. Hence, referring to the graphs, the anode current changes from D to E, when V_g changes from -3 volts to -2 volts with V_a constant at 300 volts.

Hence, mutual conductance, $g_m = \frac{\text{DE}}{1}$ mA/volt.

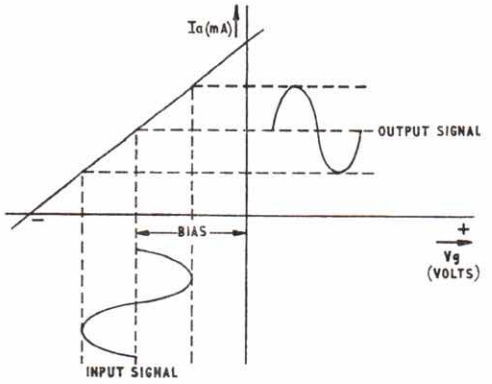
The output resistance of a transistor in the common-emitter transistor configuration is the ratio of the change in collector voltage to the corresponding change in collector current, with the base current constant. From sketch (*c*), the ratio $\frac{\delta V_c}{\delta I_c}$ is given by the inverse slope of the curves. Hence, for the curve $I_b = 80$ μA, the output resistance is given by $\frac{\delta V_c}{\delta I_c} = \frac{\text{QR}}{\text{SR}}$.

The current-gain factor of a transistor in the common-emitter configuration is the ratio of the change in collector current to the corresponding change in the base current, with the collector voltage constant. From sketch (*c*), if the collector voltage is kept constant, at say -4 volts, the collector current changes from P to Q when the base current is changed from -40 μA to -80 μA. Hence current gain, $\alpha = \frac{\text{PQ mA}}{(80-40)\mu\text{A}} = 25\,\text{PQ}$.

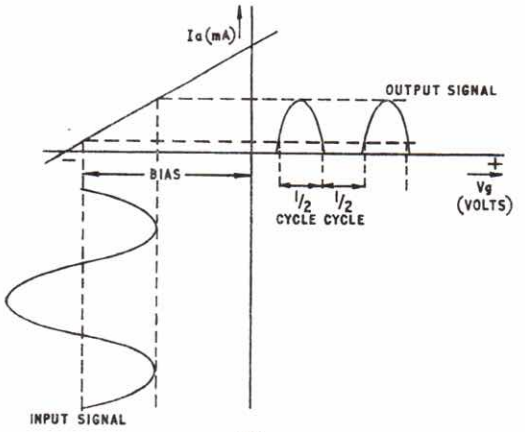
***Q.* 5.** *Explain, by reference to waveform diagrams, what is meant by (a) Class-A, (b) Class-B, and (c) Class-C operation in a tuned amplifier. Sketch and explain a circuit diagram for each of the following:*

(a) class-A tuned amplifier,
(b) class-C tuned amplifier.

A. 5. In class-A valve operation the operating point and the amplitude of the input voltage are so adjusted that anode current flows at all times during the entire electrical cycle as shown in sketch (*a*).

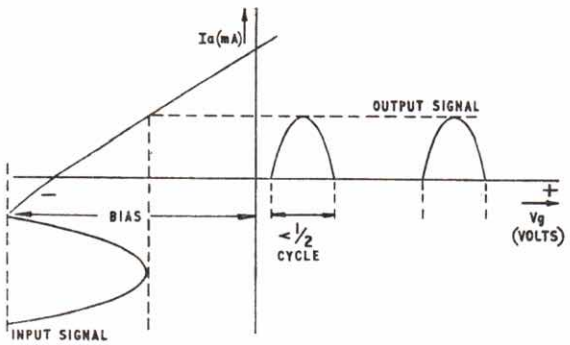


(*a*)



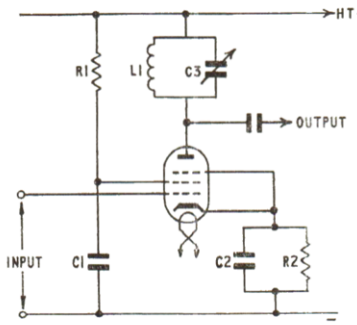
(*b*)

In class-B valve operation the bias voltage is made such that the anode current just ceases to flow in the absence of an input signal; the valve is said to be biased to cut-off. In this condition a sinusoidal input signal produces approximately half sine-wave anode-current pulses as shown in sketch (*b*).



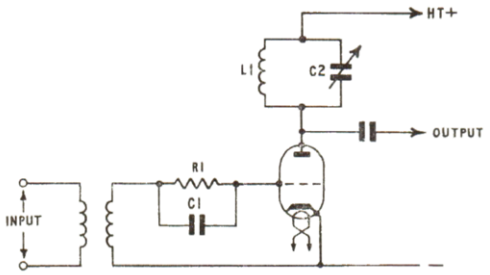
(*c*)

In class-C valve operation the valve is biased beyond cut-off and when a sinusoidal input of adequate amplitude is applied, the anode current consists of a series of pulses, each having a duration of less than half a cycle, as shown in sketch (*c*).



(*d*)

Sketch (*d*) shows the circuit of a class-A tuned-amplifier using a pentode valve. The tuned circuit L1, C3 forms the anode load of the amplifier stage which is tuned to resonance at the signal frequency. The selectivity properties of the parallel tuned circuit are used to reject any unwanted signals on either side of resonance. Cathode bias is provided by C2R2 and for class-A operation this bias is arranged so that the variations of anode current are confined to the straight portion of the valve characteristic. Screen voltage is supplied via the h.t. supply resistor R1, while capacitor C1 is used to earth the screen at signal frequencies. A pentode valve is preferred to reduce the effects of inter-electrode capacities at radio frequencies.



(*e*)

Sketch (*e*) shows the circuit of a class-C tuned-amplifier using a triode valve. The tuned circuit L1C2, forms the anode load of the amplifier, as in the class-A amplifier. In order to operate the amplifier under class-C conditions, the grid is arranged to be biased well beyond cut-off. This may be done by using a battery, but in the attached circuit automatic bias is provided by components C1R1. Class-C amplifiers are mainly used for power amplification, and triode valves are preferred. The effects of inter-electrode capacitances are reduced by neutralising capacitors, not shown in the sketch.

Q. **6.** *Explain why logarithmic units are used for expressing the ratios of powers, currents and voltages in radio and line communication.*
Define the decibel.
An amplifier has input and output load resistances of 600 *ohm. The input signal voltage is* + 16 *dB relative to* 1 μV *and the amplifier has a gain of* 30 *dB.*
Calculate:

(*a*) *the input and output voltage.*
(*b*) *the output power.*

A. 6. The use of logarithmic units for expressing the ratios of powers, currents and voltages in radio and line communication arises mainly from a practical consideration. The use of logarithmic units permits the enormous ranges of powers, currents and voltages involved in communication work to be expressed in quite simple numbers. Further, when dealing with complicated circuits, consisting of several sections (amplifiers, attenuators etc.) in tandem, it is a relatively simple matter to determine the overall ratio of the input to output powers, voltages and currents by taking the sum of the logarithmic ratios for the different parts of the circuit. Lastly, since the effect that sound intensities have on the ear is roughly proportional to the logarithm of the intensity, it is very convenient to use logarithmic units for expressing sound intensities.

The logarithmic unit used in communication work for expressing the ratios of powers, voltages, currents and sound intensities is the decibel (dB). Thus, if P_1 and P_2 are two powers and N is the number of decibels denoting their ratio then:

$$N = 10 \log_{10} \frac{P_1}{P_2} \text{ dB.}$$

The sign associated with the number of decibels indicates which power is greater. Thus a negative sign means that P_1 is less than P_2.

Since power is proportional to the square of the voltage or current, then the above formula may be written:

$$N = 20 \log_{10} \frac{V_1}{V_2} \text{ dB.}$$

$$\text{or } N = 20 \log_{10} \frac{I_1}{I_2} \text{ dB.}$$

(*a*) If the input to the amplifier is 16dB relative to 1μV, then, in the above formula, $N = 16$, V_1 is the input in μV and $V_2 = 1$ μV.

$$\therefore\ 16 = 20 \log \frac{V_1}{1} = V_1,$$

$$\log V_1 = \frac{16}{20} = 0{\cdot}8,$$

$$V_1 = \text{Anti log } 0{\cdot}8 = \underline{6{\cdot}31\ \mu\text{V.}}$$

The output voltage, $V_3 = 16 + 30 = 46$ dB relative to 1 μV. Applying the formula, where $N = 46$ and $V_1 = 1$ μV,

$$\text{then, } 46 = 20 \log \frac{V_3}{1},$$

$$\log V_3 = \frac{46}{20} = 2{\cdot}3 \text{ and,}$$

$$\therefore V_3 = \text{Anti log } 2{\cdot}3 = \underline{199{\cdot}5\ \mu\text{V}}$$

(*iii*) Output Power, $P = \frac{V^2}{R}$ where $V = V_3 = 199{\cdot}5$ μV.

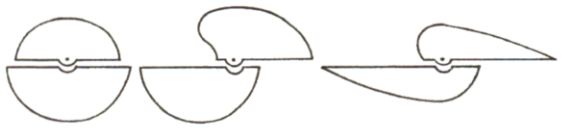
$$\therefore P = \frac{(199{\cdot}5 \times 10^{-6})^2}{600} \text{ W,}$$

$$= \frac{(199{\cdot}5 \times 10^{-6})^2 \times 10^6}{600} \mu\text{W,}$$

$$= \underline{66{\cdot}4\ \mu\text{W.}}$$

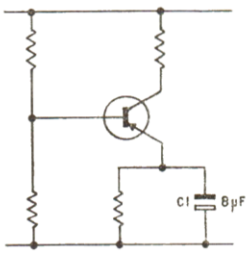
Q. **7.** *State what determines the shape of the plates required in an air-dielectric variable tuning capacitor. Give three examples.*
Give circuit diagrams illustrating three applications of electrolytic capacitors.

A. 7. An air-dielectric, variable, tuning-capacitor consists of two sets of interleaved parallel plates, one set being fixed and the other movable. Since the capacitance is proportional to the area of overlap of the fixed and moving plates, it will also be proportional to the angle of rotation of the moving plates. By suitable shaping of the fixed and moving plates it is possible to achieve a linear relationship between the angle of rotation of the moving plates with either capacitance, wavelength, or frequency.



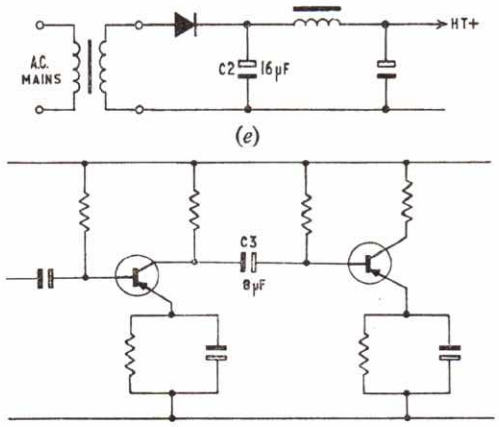
(*a*) (*b*) (*c*)

The shapes of the plates to provide these relationships are given in sketches (*a*), (*b*) and (*c*). In sketch (*a*) a linear relationship exists between the angle of rotation and capacitance. In sketch (*b*) a linear relationship exists between the angle of rotation and wavelength, and in sketch (*c*) a linear relationship exists between the angle of rotation and frequency.



(*d*)

Sketches (*d*), (*e*) and (*f*) illustrate three typical circuits in which electrolytic capacitors may be used.
In sketch (*d*) the by-pass capacitor C1 is used to prevent the alter-



(*e*) (*f*)

nating components of the emitter current from causing variations in the base current.

In sketch (*e*) the reservoir capacitor C2 is used in the smoothing circuit of ah.t. power supply for a radio receiver.

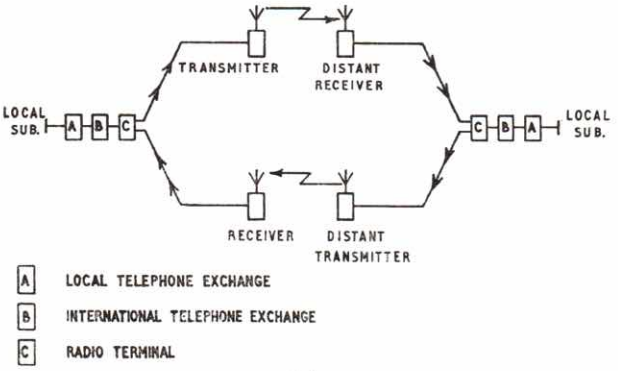
In sketch (*f*) the coupling capacitor C3 is used to provide RC coupling between two stages of an audio-frequency amplifier.

Typical values for the capacitors are shown on the circuit diagrams.

***Q.* 8.** *State the purpose and outline the operation of a 2-wire/4-wire termination in a long-distance radio-telephone circuit.*

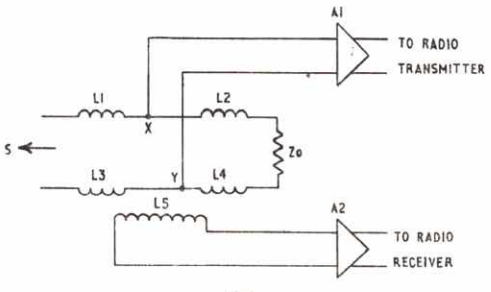
Show, by means of a block schematic diagram, the equipment needed to provide an overseas radio-telephone call between two subscribers. Your diagram should be clearly labelled to indicate the purpose of each item of equipment.

A. 8. A 2-wire–4-wire termination is necessary at the radio terminal in a long-distance radio-telephone circuit in order to split the two-way 2-wire telephone circuit into a separate 2-wire go-path to the radio transmitter, and a separate 2-wire return-path from the radio receiver. The transmitting and receiving sites must be well separated geographically. The second, complementary, purpose of the termination



(*a*)

is to arrange that there is no feedback of signals around the loop formed by the radio path at the 2-wire–4-wire termination at the radio terminal, see sketch (*a*).



(*b*)

A typical 2-wire–4-wire termination is shown in sketch (*b*). In this circuit the four coils L1, L2, L3 and L4 are identical and the terminating impedance is made equal to the line impedance of the 2-wire telephone line. With this arrangement it may be shown that speech signals from the subscriber at S will produce a voltage across XY but no voltage is induced into coil L5. The voltage produced across XY is passed via amplifier A1 to the radio transmitter. Further, signals from the radio receiving station are amplified by A2 and pass to the subscriber at S, without producing any voltage across XY. Hence no feedback occurs around the radio-path. In practice it is not possible to ensure perfect balance at the 2-wire–4-wire termination and some feedback may occur. Hence, further equipment is usually necessary at the radio-terminal, but this is beyond the scope of the syllabus.

Sketch (*a*) shows the connexions required for an overseas radio-telephone call between two subscribers on different continents.

***Q.* 9.** *Draw the equivalent circuit diagrams for the audio-frequency amplifier stage shown in Fig. 1 at low, middle and high audio frequencies.*

Use these diagrams to explain the gain/frequency characteristics of the amplifier between 0 and 15 kHz.

Calculate the voltage gain of the amplifier at the middle frequencies given that the amplification factor = 20, anode a.c. resistance = 10 k ohms, R_2 = 20 k ohms, and R_4 = 1 M ohms.

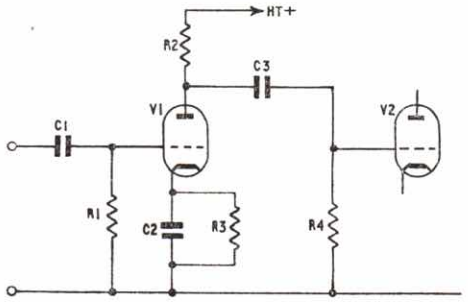
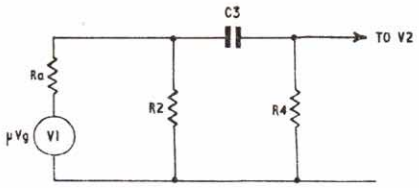
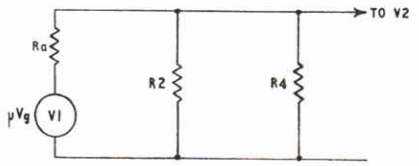


Fig. 1

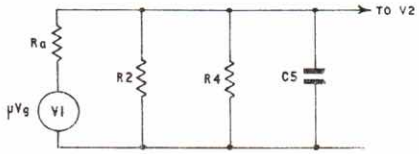
A. 9. The equivalent-circuit diagrams for the resistor-capacitor coupled audio-frequency amplifier at low, medium and high audio-frequencies are given in sketches (*a*), (*b*) and (*c*), respectively. In these circuits it is assumed that valve V1 has an anode a.c. resistance R_a and an amplification factor μ.



(*a*)

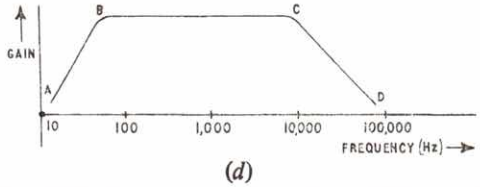


(*b*)



(*c*)

At the lower frequencies, the shunt capacitance effects may be neglected but the reactance of C3 becomes comparable with the resistance of R4. Hence C3R4 forms a potential-divider circuit, resulting in a decrease in the portion of the input voltage developed across R4 as the frequency is decreased. The effect of this on the gain of the amplifier is illustrated in section AB of sketch (*d*).



(*d*)

Over the middle frequencies, the shunt capacitance effects may again be neglected and the reactance of C3 is negligible in comparison

with the resistance of R4. The gain at middle frequencies is therefore substantially constant, as shown by portion BC of the response curve in sketch (*d*).

At the high frequencies the output capacity of V1, the input capacity of V2 and the circuit wiring capacities, all add up to give an overall effective shunt capacitance represented by C_s in sketch (*c*). Since the capacitive reactance of C_s decreases with an increase of frequency, the gain of the amplifier decreases at the higher frequencies. This effect is illustrated by section CD of sketch (*d*).

With reference to sketch (*b*) it is seen that the output voltage is produced across resistors R2 and R4 in parallel. Since the value of R4 is much greater than R2, then it may be assumed that the output voltage is developed across R2. The gain is therefore given by:

$$\text{Gain} = \frac{\mu R_2}{R_a + R_2}, \text{ where } R_2 \text{ and } R_a \text{ are in kohms.}$$

Substituting values:

$$\text{Gain} = \frac{20 \times 20}{10 + 20} = \underline{13\tfrac{1}{3}}.$$

Q. 10. *Briefly explain why a carrier is used in radio and line circuits. State the carrier frequencies and bandwidths suitable for the following applications:*

(*a*) *a local broadcast service,*
(*b*) *a long-distance overseas broadcast service,*
(*c*) *a private mobile-radio telephone service to taxis,*
(*d*) *a long-distance overseas point-to-point radio telegraphy service to ships,*
(*e*) *a group of* 24 *voice-frequency telegraph channels over a speech channel.*

A. 10. In line transmission, if more than one audio-frequency signal is passed over a pair of wires, there will be mutual interference. If, therefore, it is required to send more than one audio-frequency signal over a pair of wires the different signals will need to operate in separate frequency bands. One such method is to amplitude-modulate a series of radio-frequency carriers (higher than the highest audio frequency in the signals) with the signals, and so translate the signals to different parts of the frequency spectrum. The highest carrier frequency is restricted by the practical working limit of the line.

In radio transmission, in addition to the need to separate signals to avoid mutual interference, it is necessary to use a carrier because audio frequencies are propagated over only very short distances in free space. In radio transmission the carrier frequencies are chosen, among other reasons, by the optimum propagation conditions for the service concerned.

(*a*) To provide a local broadcast service a carrier in the v.h.f. band, normally between 80–100 MHz would be used. For a high quality broadcast service the bandwidth would be about 30 kHz for amplitude-modulated signals.

(*b*) To provide a long-distance overseas broadcast service a carrier in the h.f. band, normally between 4–25 MHz would be used. Double-sideband, amplitude-modulation would be used utilizing a channel bandwidth of 10 kHz.

(*c*) A private mobile radio-telephone service to taxis would use carrier frequencies in the v.h.f. range, between 80–460 MHz. Double-sideband, amplitude-modulation or frequency-modulation could be employed utilizing a channel bandwidth of 25 kHz.

(*d*) A long-distance, overseas, point-to-point telegraph service to ships would use carrier frequencies in the range 4–25 MHz. Allowing for such factors as frequency stability, fading and adjacent channel interference and depending whether hand-speed morse or machine telegraphy is used, the channel bandwidth may vary from 0·25 kHz to about 1·0 kHz.

(*e*) In order to send a group of 24 voice-frequency telegraph channels over a speech channel the channels are assembled at 120 Hz intervals to occupy 2,880 Hz of bandwidth within the frequency band 420–3,300 Hz. Thus the 24 carrier frequencies range from the lowest of 420 Hz up to the highest of 3,180 Hz and the bandwidth occupied is 2,880 Hz.

ELEMENTARY TELECOMMUNICATIONS PRACTICE, 1968

Students were expected to attempt not more than any six questions.

Q. 1. *Describe the general arrangements of a public communication system for automatic telephone traffic.*

In an automatic telephone area of three exchanges A, B and C, 5000 *calls per day are passed between AB,* 5000 *between BC, and* 10 *between CA. State, with brief reasons, the external line plant arrangements you would adopt to interconnect the exchanges.*

A. 1. The basic unit of the public communication system is the local exchange to which the subscribers are connected. Operation of the dial by a caller transmits signals to the exchange to operate the switching equipment which connects the caller's line to the called line.

Several local exchanges may be linked together to form a local area. Traffic to a particular exchange in a local area is identified by the initial digit (or digits) of the dialled local number; the local area is then said to have a linked numbering scheme. The whole public system consists of many local areas.

For long distance subscriber trunk-dialled (s.t.d.) traffic, the whole network is divided into a number of s.t.d. areas, each identified by an area code of the national trunk number. Each s.t.d. area, which incorporates one or more local areas, has a trunk exchange (group switching centre) which switches all the long distance traffic incoming to, and outgoing from, that s.t.d. area. The group switching centres of the network are linked by a long-distance line network which usually incorporates higher-order trunk exchanges to concentrate the long distance traffic on the long distance network.

The national trunk number consists of:

(*i*) a unique initial digit (e.g. 0) which identifies a long distance call and routes the call to the local group switching centre for further routing on the long distance network,

(*ii*) an s.t.d. area code, which in addition to determining the routing, is also used for charge determination,

(*iii*) the required local number.

The line plant used on the long distance network is usually of the high-frequency carrier or coaxial type or microwave line-of-sight radio. That in the local networks is usually audio type.

Lineplant provision is determined by the magnitude of the telephone traffic, which in turn is usually determined by the number of calls and the duration of the calls during the busy hour. It will be assumed that the call duration is reasonably the same in all the cases in the problem.

In the case AB (5,000 calls per day), assume that this is 500 calls during the busy hour, and assuming an average call duration of H hours (typically 1/20th of an hour), $500H$ traffic units would be passed during the busy hour. This traffic is assumed to justify a direct link between AB. Similarly between BC.

In the case CA (10 calls per day), and adopting the same assumptions as for AB above, $1H$ traffic units would be passed during the busy hour. As H is typically 1/20th hour, $1H$ would be small and it would not be economic to provide a direct link CA to pass this small traffic.

Thus a suitable external line network would be direct links between A and B and between B and C. Traffic between AC (and CA) would be transit switched to B to use two links. Traffic AB, BA, BC and CB would utilize one link only.

Q. 2. *A* 2,000*-ohm resistor and a* 1,000*-ohm resistor are connected in series. State, with reasons, which resistor generates the greater heat when current flows.*

Sketch and describe a typical wire-wound resistor. Give reasons for the choice of materials used for the main parts. Comment on any features in the construction for efficient dissipation of the heat.

Q. 3. *What is an inductor? One of two identical coils of wire has an iron core. State with reasons which coil would give the greater inductance value.*

Sketch and describe a typical adjustable inductor explaining how the inductance value is varied.

Q. 4. *Comment in general terms on any basic differences in construction between a capacitor of small capacitance value (about* 100 *pF) and small tolerance, and a capacitor of large value (about* 50 *μF) and large tolerance, both of low voltage working.*

Sketch and describe a capacitor of about 100 *pF value and small tolerance. Explain how the small value of* 100 *pF and the small tolerance are achieved in the construction you describe.*

A. 4. Capacitance is proportional to the effective area of the electrodes, the permittivity of the dielectric and inversely proportional to the distance of separation of the electrodes (and thus to the thickness of the dielectric). Thus the basic differences in construction between the two types of capacitor are due to these factors.

A small value, small tolerance capacitor, typically a silvered-mica type, is usually manufactured in small physical size for economic reasons. The total effective electrode area is small. Dielectrics of such small value capacitors, e.g. mica, have high performance and dimensional stability, which contribute to give a small tolerance. Further,

such capacitors allow a final adjustment of capacitance value in manufacture, typically by scraping electrode surface from the dielectric, to achieve a very small tolerance, e.g. 0·1 per cent for precision types.

A large value, large tolerance capacitor, e.g. an electrolytic type, has a relatively large total effective area of electrode for a given physical size, and an extremely thin oxide-layer dielectric. Etching the foil electrodes of electrolytic capacitors increases the effective electrode area by a factor of about six relative to the superficial area. A fabricated electrode, made by spraying molten aluminium onto a textile base material, increases the effective surface area by about ten times.

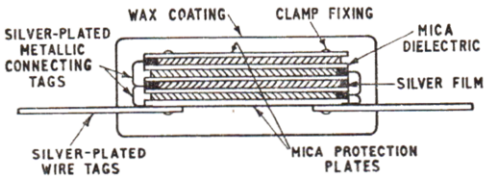
Electrolytic capacitors have low stability and large tolerance due, in the main, to the following factors:

(*a*) The performance of the capacitor is temperature dependent.
(*b*) The oxide-layer dielectric undergoes physical change and deteriorates with life.
(*c*) The capacitance decreases and the power factor increases due to diffusion of the electrolyte.
(*d*) The electrolyte undergoes chemical change with life.
(*e*) The capacitor is prone to leakage currents.

There are other factors, but the above are sufficient for the present purpose.

There are a number of types of small value, small tolerance capacitors, e.g. silvered-mica, polystyrene, ceramic dielectric. The silvered mica type will be described.

Mica can be split readily into thin laminations, free from defects such as foreign matter inclusions, cracks, etc. As an insulator it combines a high permittivity (of the order of 6–9) with low loss, independent of frequency and applied voltage, together with excellent dimensional stability, and it is not significantly affected by temperature.



The sketch shows a typical construction. The electrodes consist of films of silver deposited on the micas by firing. This process results in a capacitor of high stability, producible to close limits of capacitance. The capacitor may be of single-plate or multi-plate construction, and, when multi-plate, consists of a carefully lined up stack of silvered-mica blades. Alternate silver electrodes are interconnected by silver-plated connecting tags on the respective sides as shown. These tags connect to the respective silver-plated wire tags which form the connexions to the electrodes of the capacitor. The stack of mica blades is clamped and the fixings serve to attach the wire tags. Mica protection end-plates ensure mechanical rigidity. The assembled stack is vacuum impregnated in high melting-point wax to prevent ingress of moisture and consequent loss due to leakage currents. The wax coating forms the outer covering of the capacitor. If required a final adjustment of capacitance value may be carried out after impregnation by scraping silver away from the surface of the plates.

The small capacitance value is achieved by the relatively small effective electrode area and the relatively large thickness of the mica dielectric. The small tolerance aspect has been included in the construction description above.

Q. 5. *What do you understand by* (*i*) *float charge, and* (*ii*) *trickle charge, with reference to batteries?*

Describe, with a diagram, a float method of operating a 50-volt battery installation. Explain:

(*a*) *how the cells are connected together,*
(*b*) *the arrangement for achieving a close tolerance voltage output.*

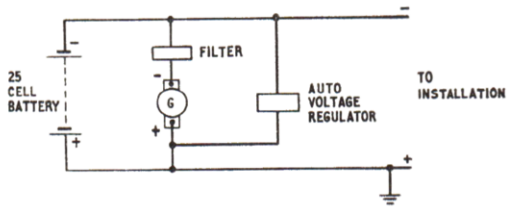
What factors determine the ampere-hour capacity of the battery?

A. 5. (*i*) In float methods of operating lead-acid secondary cell batteries, the battery itself does not supply the power to the installation. Substantially all the power is taken from the mains, being derived from a rectifier or a d.c. generator, the output of which is connected to the installation. Although the battery is also connected across the bus bars, it neither charges nor discharges appreciably, but the operating conditions vary. There may be negligible charge or discharge of the battery or alternatively the battery may discharge on heavy load, the rectifier giving maximum assistance to the discharge. As the load decreases the rectifier supplies more and more of the load, finally taking all the load and commences to charge the battery. The charging continues at a gradually decreasing rate as the battery voltage rises.

(*ii*) A trickle charge is a continuous charge at a low rate sufficient to compensate for the internal losses of the battery and maintain the battery in a fully charged condition. The term is also applied to very low charge rates which are sufficient, not only to compensate for internal losses, but to compensate for intermittent discharges of small amounts which occur under service conditions. Typically a trickle charge may be applied:

(*a*) to a battery in "wet storage" to maintain the specific gravity constant,
(*b*) during idle periods between float cycles to make up loss due to local action,
(*c*) to compensate for a small loss of charge when a battery floats in certain float methods.

The sketch shows a simple float scheme. A mains-operated a.c. motor drives a shunt wound d.c. generator. The battery is floated



across the generator at a voltage which is regulated between the desired limits. The automatic voltage regulator, controlled by the p.d. across the installation bus bars, regulates the voltage by varying the resistance in the field-winding circuit of the generator. The filter in series with the generator smooths the generator output, otherwise a "noisy" supply to the installation would result. In the typical situation of a nominal 50-volt supply to an installation, the voltage is regulated between 50·5 volts and 51·75 volts, the terminal p.d. of each of the 25 cells of the battery being between 2·02 and 2·07 volts. In this situation the battery charges and discharges are very small and some arrangement would be required to trickle charge the battery to make up losses due to local action. The 25 cells are connected in series, positive terminal of one cell to the negative terminal of the next. The bus bars are connected to the extreme end cells, e.g. positive from the positive terminal of cell 1, and negative from the negative terminal of cell 25. The connecting links, cable or bus bar would require to be of sufficiently low resistance to carry the maximum current with negligible voltage drop.

In theory, the capacity of a float battery can be small, as the battery, in normal service, is not required to supply the full load. In practice the capacity must be such as to meet a desired reserve to cover periods of mains supply failure, and in this condition the battery must supply the full load. Thus the ampere-hour capacity of a float battery is determined by the maximum load current and the duration of mains failure assumed to apply, typically 12 hours.

Q. 6. *State the basic differences in the construction of multi-pair cables for* (*a*) *internal use and* (*b*) *external underground use.*

With the aid of a simple sketch describe a multi-pair cable (about 30-pair) for internal use. Explain how the conductor identification in this type of cable differs from that of external underground cables.

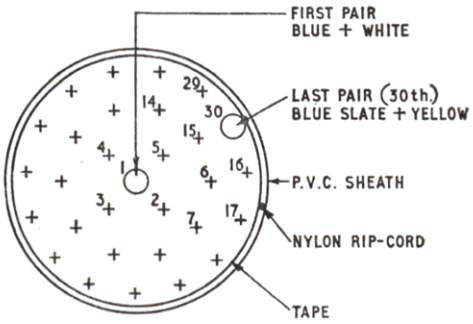
A. 6. The basic differences in the constructions are:

(*i*) The wire-insulation of p.v.c. (polyvinyl-chloride) internal cables is heavier than that of the paper insulation in external cables as the conductors of the internal cable must withstand more handling and soldering.

(*ii*) The sheath of the internal cable is lighter and more flexible than the sheath of an external cable as the internal cable must follow the bends of cable-runs and is not usually fitted in wet situations.

(*iii*) The conductors of the internal cable are generally of lighter gauge than those of the external cable as the runs are considerably shorter and thus conductor resistance is not such a significant factor.

(*iv*) The internal cable size, typical maximum 100 pairs, is less than that of the external as the internal cable must be more flexible and more easily handled.



The sketch shows a typical 30-pair p.v.c. internal cable. For most purposes the annealed tinned-copper conductors are 6½ lb/mile, although heavier gauges are available for extra long runs or power

supplies. They are insulated with hard-grade p.v.c. about 8 mils thick which is self-coloured for single-coloured wires and continuously-spiral-coloured for the multi-coloured wires. The standard colour scheme applies, and for the 30-pair cable the first 20 are paired with white and the remaining 10 with yellow. Thus, the colours for pairs 1–30 respectively are, Bl, O, G, Br, S; Bl–W, Bl–O, Bl–G, Bl–Br, Bl–S; O–W, O–G, O–Br, O–S; G–W, G–Br, G–S; Br–W, Br–S; each paired with white, and Bl, O, G, Br, S; Bl–W, Bl–O, Bl–G, Bl–Br, Bl–S; each paired with yellow, where Bl, O, G, Br, and S are blue, orange, green, brown, and slate, respectively.

The two wires of a pair are uniformly twisted in about a 4 in. lay, and the pairs are stranded in layers around the first pair (the blue–white pair in the 30-pair cable), the order of stranding following the standard colour scheme.

The layers in cables containing 61 wires or less are stranded with a left-hand lay whilst the stranding lays for all larger size cables alternate with each layer from left-hand to right-hand. The core of pairs is tightly lapped with polyethylene tetraphthalate tape, and the whole is sheathed with cream coloured p.v.c. about 30 mils thick. A nylon rip cord is laid under the sheath to facilitate sheath removal.

Conductor identification of both the internal and external cables is by a colour scheme, but as the size of the external cable can be very much greater than internal, it would be difficult and complicated to achieve identification by unique conductor colour alone. For this reason, for external cables, greater significance is attached to layer identification, and the position of pairs in the layer. Because of this, "spaced-line" marking (1, 2, 3 or 4 lines on the paper insulation) is adopted for external cables, but not for internal.

Within the unit of the unit-twin external cable, the colour of the lines differentiates between adjacent layers and between the two marker-pairs and the other pairs in each layer. The position, or numbering, of pairs in the layer commences with the first marker-pair and follows clockwise with the second marker-pair, and so on. The marker-pairs in the centre and even numbered layers are spaced-line marked green (1 and 2 lines for the first pair; 3 and 4 lines for the second pair) and the remaining pairs are marked red. The marker-pairs in the odd layers are orange and the other pairs are blue.

In star-quad external cables, the spaced-lines of alternate quads in each layer are red or blue. The first quad (the marker) is red, the second, fourth, etc., blue, the third, fifth, etc., red, and the last quad (the reference) blue. Cotton whippings around the quads are white for the centre and even layers, and black for the odd. The marker and reference quads in each layer have an additional orange whipping.

In internal cables it is not necessary to discriminate between layers or between positions of pairs in the layer. Each pair has a unique colour combination and as no other pair in the cable would have these colours, complete identification is achieved.

***Q.* 7.** *Why is a flux used when soldering a wire to a tag and what are its desired characteristics? Is flux used when wrap-jointing (as distinct from soldering) a wire to a tag? Give reasons.*

Describe the process of wrap-jointing a wire to a tag, pointing out how a good electrical connection is achieved. Can this type of joint be used when the connection is required to be broken and re-made reasonably often? Give reasons.

A. 7. The adhesive strength of a soldered joint depends upon intimate molecular contact between the solder and the metal. This is not possible unless the solder wets the surface of the metal, and this cannot occur unless the surface of both the solder and metal are chemically clean. The flux performs the function of chemically cleaning the solder, wire and tag surfaces. The desired characteristics of flux are as follows:

(*i*) It should clean the metal and remove oxide from the solder.

(*ii*) It should be stable under heat during the soldering process, to maintain continual freedom from oxide formation.

(*iii*) Any residue of flux should be chemically neutral and hard to give protection to the joint against atmospheric conditions.

For soldering a wire to a tag, the flux usually consists of resin, with the addition of a little activating agent such as alcohol, either ethyl or butyl, or white spirit.

A wrapped joint gives a far better mechanical joint than the soldered joint, and flux, functioning as an adhesive between wire and tag in the soldered case, is not necessary for this purpose in the wrapped case. A wrapped joint consists of many cold-weld points between wire and tag, and the tight wrapping process breaks through any surface films on wire or tag. Flux, functioning as a cleaner in the soldered case, is thus not necessary for this purpose in the wrapped case.

A wrapped joint connection necessitates a solid conductor, stranded conductors not being permissible, and a rectangular cross-section terminal. The jointing process consists of a tight wrap of some six turns of the wire around the tag. A wrapping gun is used to achieve the tight wrap. The bare end of the wire is threaded into the end of the gun, the gun end is then placed over the tag end, and the gun revolved to wrap the wire around the tag. In the wrap the edges of the tag bite into the wire to form a virtual cold weld, the success of the process depending upon this bite. In this type of joint there is a negligible risk of a high resistance connection and a good mechanical connection is implicit in the technique.

The wire in a wrapped joint tends to set in the tight turns and repeated removals of the wire from the tag would tend to break the wire. Thus the type of wrapped joint described, i.e. a primary wrapped joint, is not suitable when the connection is required to be broken and remade often, being more suitable for joints of a permanent or semi-permanent nature. The secondary wrapped joint overcomes this difficulty, but the joint is complicated and not often used. The conductor to be connected is placed along the surface of the tag but not wrapped. A separate small length of wire is then wrapped around both tag and conductor, the tight turns binding the conductor to the tag. Breaking of the wrapping wire on repeat jointing is of no consequence.

***Q.* 8.** *Make a simple sketch of a non-polarised relay and with reference to this:*

(*a*) *indicate the magnetic path,*

(*b*) *indicate the materials used for the various parts of the magnetic path,*

(*c*) *explain how the relay operates,*

(*d*) *explain how the relay releases efficiently,*

(*e*) *explain how the one construction of magnetic path is used to operate both light and heavy relay spring loads on different relays.*

***Q.* 9.** *Describe, with a sketch, the principle of operation of a modern telephone receiver.*

State, with reasons, whether or not the receiver concerned could be used as a microphone.

***Q.* 10.** *What do you understand by the following in respect of underground cable plant:*

(*a*) *insulating gaps,*

(*b*) *cathodic protection?*

Describe the general arrangements of each and comment on the similarities and differences in the respective basic principles of operation.

State, with reasons, the type of underground cable on which insulating gaps and cathodic protection would be used. Which type of underground cable can be used without them?

A. 10. Both (*a*) and (*b*) are methods used to minimize electrolytic corrosion of lead cable sheaths.

(*a*) Insulating gaps are inserted in the lead sheath to break the electrical continuity. This gives a comparatively high sheath resistance to stray currents so that much less is picked up, less is discharged in the anodic area, and sheath corrosion is reduced. Insulating gaps are fitted approximately midway between sheath-current pickup and discharge areas. They are usually located in manholes or large jointing chambers. They should not be fitted where the current tends to leave the sheath because they may then make the current leave from shorter lengths of cable and so cause greater risk of electrolytic corrosion.

To make a gap, about 8 in. of the lead sheath is dressed so as to be as near circular as possible without appreciably compressing the cable. The rounded length of cable is roughened, circumferentially, with a rasp. A strip of sheath, $\frac{1}{4}$–$\frac{3}{4}$ in. wide is removed from the middle of the dressed portion. This gap in the sheath is built up to the same thickness as the sheath with a tight wrapping of rubber adhesive tape, and a split rubber sleeve is placed over the tape. An aluminium coupling is next placed over the rubber sleeve, and rubber spacers fitted between flanges of the coupling which are then drawn tightly together with nuts and bolts.

(*b*) Cathodic protection is a general term applied to methods which minimize corrosion by not allowing the sheath current to leave the sheath by an electrolytic path, such as damp earth, duct water, etc. The technique can take a number of forms:

(*i*) Bonding cable sheaths to power station bus bars or negative feeders to provide a completely metallic path for leakage currents.

(*ii*) Connecting a source of negative potential between cable sheath and a low resistance earth so as to minimize the possibility of current leaving the sheath.

(*iii*) Using a sacrificial anode. A block of magnesium is connected to the cable sheath by an insulated wire and buried in the ground near the cable. Calcium sulphate (gypsum) is packed around the block to ensure a constant and low resistance between it and the soil. The magnesium block acts as the anode so that any stray currents in the sheath, which now acts as the cathode, flow through the connecting wire to the magnesium anode. Corrosion takes place at the magnesium block and not at the cable sheath, and thus the block is "sacrificed" to save the sheath.

The similarities are that both techniques aim to minimize electrolytic corrosion, and both assume the presence of sheath current conditions. The basic difference is that method (*a*) aims to prevent sheath-current flow, whereas (*b*) allows sheath-current flow, but aims that it leaves the sheath to the electrolytic earth via a metallic path and not directly.

Insulating gaps and cathodic protection would be used where the sheath material is a good electrical conductor, and thus in lead-sheathed underground-cable plant. Such a material offers little resistance to sheath-current flow. There is no requirement to use the methods on underground-cable plant with sheaths of insulating material such as polythene. Such material offers high resistance to sheath-current flow and virtually eliminates it.

LINE PLANT PRACTICE A, 1968

Students were expected to answer any six questions.

Q. **1.** *What factors should be taken into account in selecting a suitable site for a distribution pole? What are the relative advantages and disadvantages of using insulated drop wire and open wire for subscribers' distribution?*

A. 1. The following factors should be considered in siting a distribution pole (d.p.):

(*a*) A site should be chosen so that the maximum number of tenancies can be served radially from the pole without additional fixtures or poles. If additional poles are required to serve the d.p. area, care should be taken to site the d.p. so that any subsidiary poles can, if required, be converted to d.p.'s in future.

(*b*) The position should be such that all tenancies can be served without difficulties due to trees, buildings or power wires. Care should also be taken to avoid wires passing close to windows.

(*c*) The pole should not obstruct entrances to property, or views from windows and should not create a hazard to pedestrians or vehicular traffic. It should be clear of lamp standards and road signs.

(*d*) If possible the pole should be sited on the public footway and in a position which will not be affected by future road widening schemes. Its exact position will depend upon the wishes of the local authority, since some authorities prefer the pole sited on the fence line, whilst others prefer the kerb line.

(*e*) Consideration should be given to other undertakers' plant and the ease of erection and maintenance of the pole and wires. A site near to an existing underground track would be an advantage.

The advantages of using covered drop-wire rather than open wires are as follows:

(*a*) It is cheaper and easier to erect and requires less maintenance.

(*b*) There is a reduction in the quantity and size of the plant items required.

(*c*) No joints are required between the block terminal on the d.p. and the block terminal in the subscriber's premises.

(*d*) It can be used through trees, and some types can be used for crossing low and medium voltage power lines.

(*e*) It is not subject to corrosion.

(*f*) It is not subject to humming (wind noise) and does not require game guards.

The disadvantages of using covered wire rather than open wire are as follows:

(*a*) Although the plant items needed for supporting the cable drop wires are smaller than those used for open wire, the drop wire itself is more conspicuous and is frequently considered objectionable in residential areas. The use of new thinner types of drop wire is overcoming this disadvantage.

(*b*) If a fault develops in the drop wire, other than in the terminations, the whole length has to be renewed.

Q. **2.** *Explain how you would carry out a survey for the provision of a light overhead route along a country road to serve a farm. What are the main factors to be considered and to what extent can preparations be made in advance of the actual work?*

A. 2. Before commencing the actual physical survey, it is necessary to obtain an ordnance survey map showing plant details of the area concerned, and the position of the farm and the nearest distribution pole (d.p.). A forecast of total requirements along the country road is next obtained; this may indicate the possible use of long-line construction. Also required are the views of the local authority to the proposed erection of the route, and details of any other services, e.g. sewers, water, gas and electricity. It may be possible to carry out joint construction with the local electricity board over part of the route.

Tentative pole sites are plotted on the map, taking particular note of the following factors:

(*a*) town and country planning schemes,
(*b*) future road widening operations,
(*c*) underground power circuits,
(*d*) overhead power circuits,
(*e*) nearby airfields,
(*f*) trunk or special roads, rail and river crossings,
(*g*) places of special beauty,
(*h*) sharp bends in the road.

The physical survey can now commence, the ordnance survey map, a set of measuring rods, a clinometer and a survey book will be required. First of all the tentative pole sites are checked and the final positions marked on the ground and on the map. The use of measuring rods will help in deciding the final pole positions, and the clinometer can be used to find out the heights of any obstructions.

In selecting the final positions of the poles, further factors should be considered. The span lengths should be kept as nearly normal as possible, but variations may be necessary to avoid entrances to private property, to obtain improved facilities for the siting of a stay or strut, to avoid obstructions such as trees and buildings, to avoid exposure to traffic, at narrow sections of the road, bridge approaches, etc., and to avoid having to excavate deep pole holes, such as at sharp bends and ditches. It is also desirable to avoid acute angles in the line by shortening spans. The line should be so planned that road crossings, if not entirely avoided, are reduced to the minimum. The poles should be erected on public property, if possible, for ease of maintenance and wayleave considerations. Care should be taken to avoid siting the poles where there may be a risk of damage to other undertakers' plant during the excavation of the pole holes.

When the most suitable pole sites have been selected, a complete record of all the information required for the preparation of a detailed estimate, the requisitioning of the stores and the guidance of the working party should be compiled in the survey book. This record should include the following:

(*a*) the exact position of each pole, stay and strut,
(*b*) the size and class of each pole, based on the ultimate wire capacity required and the clearance necessary over roads, farm entrances, road overhangs, etc,
(*c*) advice on the method of excavating pole holes and erecting the poles, and any special tools required,
(*d*) the sizes of stays and struts, the number and type of arms, and the number and type of wires to be erected initially,
(*e*) particulars of any special stipulation, e.g. game guards,
(*f*) details of any private wayleave or permission for tree-cutting that may be required,
(*g*) details of any protective measures necessary,
(*h*) details of where joint construction with the electricity authority is possible,
(*i*) details of the termination at the farm.

The following preparations can be made in advance of the actual work on site:

(*a*) The necessary wayleave consents, both public and private, should be obtained, and the relevant notices under the Public Utilities Street Works Act should be sent to the appropriate authorities.

(*b*) Permission for any tree cutting should be obtained.

(*c*) The means of cartage, delivery and layout of materials, and the availability of any special tools likely to be required should be decided upon.

(*d*) It should be checked that a spare cable-pair is available from the d.p. to the exchange.

Q. **3.** *Describe the process of erecting a* 15*-pair, self-supporting, figure-of-eight aerial cable (i.e. incorporating the supporting wire within the sheath) on an existing pole route. Describe in detail methods of attaching the cable to the poles.*

A. 3. The existing pole route should first be surveyed and strengthened where necessary by permanent or temporary staying. All fittings needed should be placed in position before cable is erected. Cable is usually erected on the road side of poles, but at angle poles where the cable is not jointed and the pull-on-pole is greater than 5 ft, the cable is placed on the inside of the angle so that it pulls away from the pole.

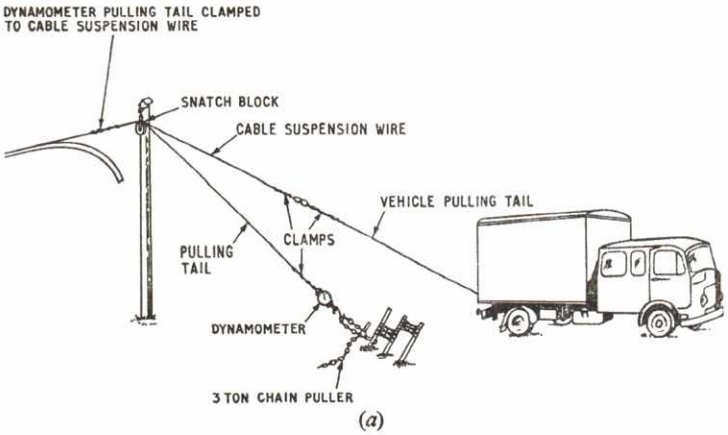
The cable drum is set up in the usual way and the cable run out along the ground, care being taken to pass the cable on the same side of the pole as the fittings. One end of the cable is terminated, then at intermediate poles on straight sections of the line, the cable is lifted and laid over the spacing washers with the bracket secured finger tight in a vertical position. At intermediate angle poles, the cable is lifted and placed on the support inside the shackle, the shackle pin is then screwed down tightly using a spike or bar.

Six complete twists of the cable are inserted in each span to prevent wind-induced movement (galloping). The twists are inserted on straight-through positions after the cable has been tensioned and before the cable is fixed in the bracket. Where two or more poles with shackle fittings are next to each other, it is necessary to insert the twists at the time of placing cable in the fitting before tensioning.

At the tensioning end of the cable route, the suspension wire is extracted from the sheath for an amount approximately equal in length to the height of the termination above ground, then fed through a snatch block fixed at the top of pole. The suspension wire is turned back on itself to form an eye and secured with four clamps. A suitable length of suspension wire is fixed through this eye and connected to a pulling vehicle so that the slack cable can be pulled up.

A pulling tail of 4/14 or 7/16 wire is attached to the suspension wire with clamps, then passed through the snatch block and the end attached to a dynamometer which is connected to a chain-puller held in position by crowbars driven into the ground. The arrangement at the tensioning end is as shown in sketch (*a*).

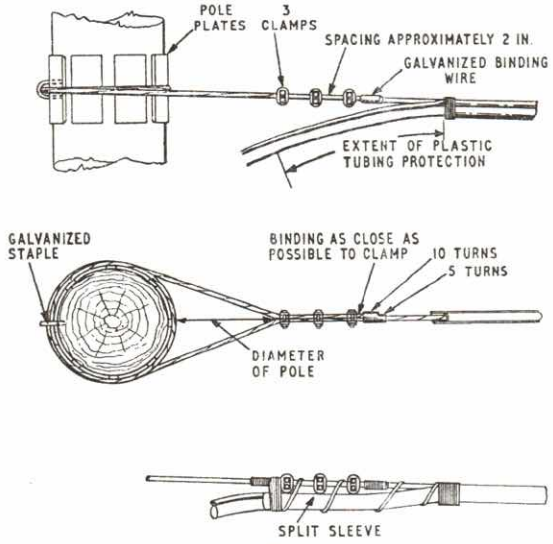
The cable is now tensioned to 200 lb greater than tabulated values for spans up to 70 yds according to the temperature, and left until it has been assured that the tension has equalized throughout the section. The tension is then reduced to the specified value. With the suspension wire held at the final tension, the cable is terminated and the tensioning gear removed. The cable is then twisted and bolted into the bracket at through positions where the pull-on-pole is 5 ft or less. At angle poles, where it has already been twisted, the cable is bound to the aerial-cable support.



(*a*)

For the termination of cable at the beginning and end of each section, at poles where the pull-on-pole is 30 ft or more, and also at jointing points, the suspension wire is first separated from the cable for a length equal to the length of termination, plus the length down the pole, sufficient to enable a joint to be made. A sharp knife is used to slice off the top of the p.v.c. covering from the wire and the suspension wire is pulled out of its sheathing, which must not be trimmed off. Several turns of binding wire are applied to the cable where the suspension wire leaves the sheath, to prevent the cable from tearing off the suspension wire at this point.

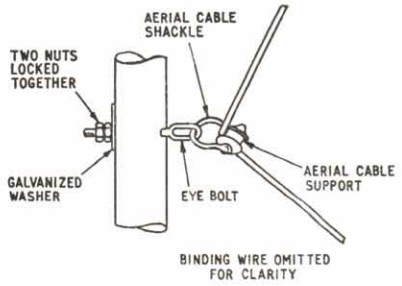
Pole plates are fixed to the pole at the required height and the suspension wire taken twice round the pole and secured by three clamps applied at 2 in intervals with the first at a distance equal to the pole diameter away from the pole. A staple is then hammered into the pole to maintain the termination at the correct height. The spare suspension wire is cut off and the remaining end bound to the main strand.



(*b*)

A length of split plastic-tubing 2 in in diameter is fitted over the cable as shown in sketch (*b*) and bound to the suspension wire to prevent the clamps from chafing the cable sheath.

The method used at angle poles where the pull-on-pole is 5–30 ft and at canal, building and road crossings requires the pole to be bored for an eye bolt which is fitted with its eye in the horizontal plane. The shackle is assembled in the eye of the bolt with the cable support assembled on the shackle pin. The head of the pin and also the

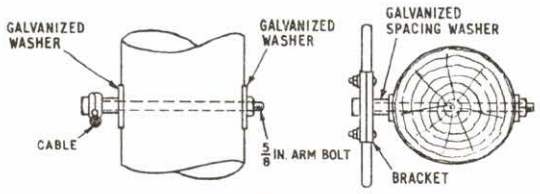


(*c*)

smaller flange of the cable support are uppermost as shown in sketch (*c*).

After the cable has been erected and tensioned it is firmly bound to the support with p.v.c. insulated binding-wire. With the cable lying snugly in the support (suspension wire upwards), the middle of a 3 ft length of binding wire is laid across the cable to one side of the support and three close turns made round the cable. A similar binding is made on the other side of the support. Each pair of wires is then pulled tight, taken round the underside of the cable support and made off on the cable, the p.v.c. being stripped from the binding wire and the wires twisted together.

The method of fixing at straight-through positions where the pull-on-pole is 5 ft or less, utilizes a bracket which is assembled on a bolt



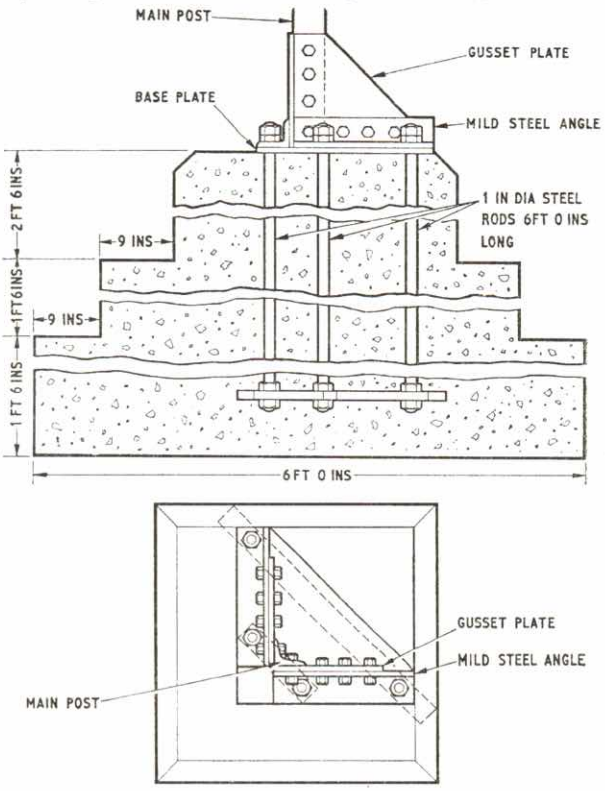
(*d*)

with a spacer and two galvanized washers. The bracket has a groove along its length which accommodates the insulated suspension wire and clamps it tightly, see sketch (*d*).

Q. **4.** *Briefly describe a common type of self-supporting steel mast suitable for carrying an aerial* 125 *ft high.*

With the aid of sketches, describe in more detail the construction of the foundation for such a mast.

A. 4. A self-supporting steel mast is normally a lattice construction of L-section mild steel members bolted together. The mast consists of four main posts secured to individual foundation blocks which are spaced to give an adequate base. The main posts are connected and strengthened by diagonal and horizontal external bracings and internal cross bracings spaced at intervals throughout the mast. The sizes of members and spacings quoted below are typical for a mast required to support an aerial at 125 ft. At the base, the four main posts consist of 13-ft lengths of 4 in × 4 in × $\frac{1}{2}$ in L-section mild steel. Each of these main post sections overlaps the next section which is 4 in × 4 in × $\frac{3}{8}$ in mild steel and the sections are bolted together. Subsequent sections are connected in a similar manner, the sections reducing in size until, at the top, the main posts consist of four 27-ft lengths 2 in × 2 in × $\frac{5}{16}$ in L-section mild steel. The diagonal connecting-members and bracings are 3 in × 3 in × $\frac{1}{4}$ in. L-section mild steel at the base reducing to 2 in × 2 in × $\frac{5}{16}$ in at the top. The top of the mast is reinforced with four $\frac{1}{4}$ in mild steel corner plates and is surmounted by two lengths of L-section mild steel bolted together supporting a gusset plate at each end. The mast is approximately 9 ft square at the base and 1 ft square at the top.



The foundation for each of the four posts of such a mast is illustrated in the sketches. A 1-in thick mild-steel base plate and two lengths of 4 in × 4 in × ½ in L-section mild steel are secured by means of four 6 ft long, 1 in diameter threaded steel rods embodded in the foundation block. Gusset plates of ⅜ in thick mild steel are secured to each length of mild steel angle and the main post is bolted to the gusset plates and mild steel angles. At the base the main posts are bent at their lower ends so that, at the gusset plates, the main posts are vertical.

Q. **5.** *Explain in detail the qualities required of the ingredients used for making concrete. Describe the process of mixing the concrete and laying it for the floor of a manhole. How would the process you describe be affected by the weather conditions?*

A. 5. The ingredients for making concrete are cement, aggregate, sand and water. The qualities required are as follows:

(*a*) *Cement*—this should be of good quality, newly obtained in sealed bags, feel silky to the touch, be free from lumps and feel warm if a hand is plunged into the bag.

(*b*) *Aggregate*—this should be clean, screened river ballast, gravel, stone or other approved material of the nature of cubes (not flakes), and well graded in size. It should be free from dirt, floury stone dust, loam and earthy or like materials.

(*c*) *Sand*—this should be obtained from river or pits and should be clean, sharp, gritty, and free from loam, organic matter and adherent coatings.

(*d*) *Water*—this should be clean and fit for human consumption.

Special attention should be paid to cleanliness at all stages of mixing and placing concrete. Mixing for the floor of a manhole may be done by machine or manually. The ingredients should be measured in gauging boxes or by other means, e.g. buckets, thus ensuring the use of the correct quantities of each ingredient by volume. The mixing must be thorough. When manual mixing is employed, the platform on which the operation is performed should be large enough to permit the material to be moved completely from one place to another in the course of being turned over. Before adding the water, the dry material should be repeatedly turned over until the mixture is an even colour throughout. Mixing should then be continued while gradually adding the water, until the correct proportion of water is included. The whole mass should then be turned until thoroughly mixed. The water should be applied through a rose or sprinkler only to the extent required to obtain a wet mixture with a plasticity that will permit convenient placing and compacting throughout the structure.

The essential features of laying the concrete for the floor of a manhole are that the concrete should be placed, not thrown, into position as quickly as possible after being mixed and it should be lightly tamped and worked to fill all cavities. Mixed concrete should be used within 30 minutes.

The process is affected by the weather in that concreting should not take place in temperatures below 40° F unless special cement is used. Concrete, when placed, should be protected against frost, particularly overnight. In warm and windy weather concrete should be prevented from drying too quickly by shielding it from the sun and wind. It should be kept moist for a few days by frequent sprinkling with water from a hose or watering can or by covering it with wet sackcloth or wet sand.

Q. **6.** *Describe the work of providing an underground two-way duct route across the carriageway of a suburban road, including the provision of two brick surface entrance joint boxes in the opposite footways.*

A. 6. After placing suitable warning notices and barriers in position, the line of the trench to be excavated is marked out, and pilot holes opened to ascertain the position of other services or possible obstructions. In order to permit the flow of traffic, it will be necessary to dig the trench only half-way across the road and to complete the crossing in two halves.

The trench should be dug as straight and narrow as possible, consistent with working conditions. Normally 15 in width is required for a two-way duct, but there must be no undercutting to avoid reinstatement. The depth of the trench should be sufficient to provide a minimum of 24 in between the road surface and the top of the duct. To ensure a satisfactory backfill, which will not subsequently sink, the excavated materials should be carefully segregated in order that they may be replaced as nearly as possible in their original positions. As far as is practicable the excavations and the excavated materials should be protected from either losing water by drying out or gaining water by being exposed to rain.

The bottom of the trench should be well punned so that the duct will be laid on a firm, level bed of soil. The first duct is then laid with the socket towards the layer and the spigot end positioned so that it can be incorporated in the wall of the new joint box. A groove is dug across the trench so as to comfortably accept the collar of the duct and so that when in position, the duct lies firmly on its barrel. The spigot of the second duct is placed into the socket of its predecessor, and is levered home with a plank of wood against the socket-end of the duct. When the second and subsequent ducts are laid, the socket of the previous duct and the spigot of the duct being laid are painted with a bituminous-emulsion jointing compound, which may be applied cold. Great care must be taken to ensure that no dirt or similar foreign matter adheres to the spigot or socket during jointing. A mandrel, with a following rope, is placed in each bore of the duct and is drawn forward as laying proceeds. A close watch must be maintained to see that the ducts do not deviate appreciably from the intended line, and errors should be corrected immediately.

As soon as possible backfilling should be started using fine soil, free from stones, which should be placed between the sides of the duct and the excavation, and thoroughly compacted using a hard punner or suitable piece of wood. When the gaps at the side of the duct have been filled, fine material is placed over the barrel of the duct and again thoroughly punned, this process continuing until 3 in of cover has been provided. Backfilling is then completed in the reverse order in which the materials were removed, replacing them in layers of about 6–9 in at a time, and well consolidating each layer by hand or mechanical punning before a fresh layer is added. Backfilling in this way continues until there is only sufficient space to accommodate the surface material which is then returned to the trench and thoroughly punned. A 1½ in layer of tarmacadam or cold asphalt is then used to seal the trench and to provide a running surface until the permanent restoration is carried out. Finally, the cut edges of the existing road surface should be cleared and treated with a 30 per cent bitumen emulsion to provide a bond between the new and the old material. If the tarmac or cold asphalt is not of sufficiently close texture to seal the trench against ingress of water, the surface should be treated with a suitable tar or bituminous coating to give the necessary seal.

The process is repeated for the second half of the road until the crossing is completed. The spigot end of a special double-spigot duct, or the broken end of an ordinary duct, is laid ready to be incorporated in the footway box to be built on the other side of the road. The working mandrels are then removed and test mandrels and brush are drawn through the duct bores in both directions, finally leaving a draw-rope in each way. The ends of the duct are then plugged with hardwood plugs.

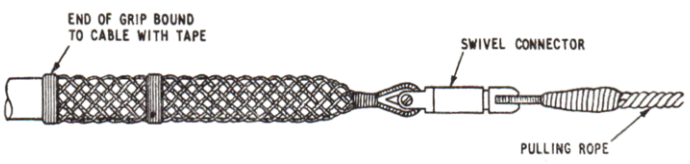
The size of the joint-boxes provided must be of such dimensions that adequate space is provided to pull-in and joint the maximum size cables that they are expected to accommodate. Typical internal dimensions would be 2 ft 3 in deep, 4 ft 4 in long and 2 ft wide.

To construct the jointboxes the footway should be excavated to the required dimensions, the sides of the excavations being timbered if necessary. The foundation should then be levelled and rammed, and a concrete floor laid level to the required thickness, a fall of 1 in for drainage purposes being achieved by cement rendering. Brickwork for the walls should be laid in cement-mortar and flush pointed. In dry weather the bricks should be dipped in water before they are laid. Cable-bearer bolts should be fitted as the walls are erected. Channels to accommodate the joint-box covers should be bedded in Portland cement mortar at or as near the correct level as possible. The cross-piece, where provided, should then be fitted and the covers placed in the frame. If the covers rock, packing pieces of hard material should be placed either beneath the lowest corner of the channel, or under the channel at the cross-piece position until rocking is prevented and the cover lies level and firm. Finally, voids below the channel should be completely filled with cement mortar to the same level as the packing.

Q. **7.** *Sketch and describe a method used for attaching the end of a* 1,000*-pair,* 4 *lb, paper-insulated, polythene-sheathed cable to a rope prior to drawing the cable into a duct.*

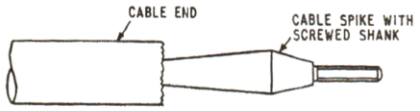
Assuming that the cable is to be drawn into a duct via a manhole, show, by means of a sketch, a typical arrangement for the drum and any apparatus used to ensure that the cable is not damaged during the process of drawing it in.

A. 7. A pulling rope is attached to the cable in the following manner. The sealed end of the cable is cut off, and in order that the pulling strain is taken by the core and not the sheath, the end is consolidated by driving a tapered steel spike lengthwise into the centre of the core. The cable is then resealed with compound and a steel-wire-mesh cable-grip drawn over the cable-end to its fullest extent so that the lattice tightens. The open end of the grip is securely taped and a second tie made 9 in from the pulling eye. The cable grip is coupled to the rope through a swivel connector to prevent the cable twisting during drawing-in. Sketch (*a*) shows this arrangement.



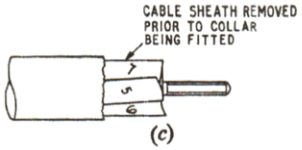
(*a*)

An alternative method of attachment is for the cable-end seal or cap to be removed and a tapered spike with a screwed shank driven into the core of the cable using a drift to protect the thread of the



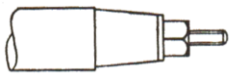
(*b*)

shank, see sketch (*b*). The drift is marked so that the spike is driven into the correct distance. A 1½-in length of the cable sheath is then removed exposing the insulated conductors, see sketch (*c*). A tapered



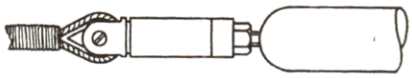
(*c*)

collar is passed over the cable and pushed on as far as it will go. A washer is fitted over the shank so that it rests on the shoulder of the collar and a nut is screwed down upon it forcing the collar down to the sheath end and pulling the spike out into the collar. The conductors are thus trapped between the spike and the collar, see sketch (*d*). A plastic sleeve is finally fitted over the cable end and taped onto



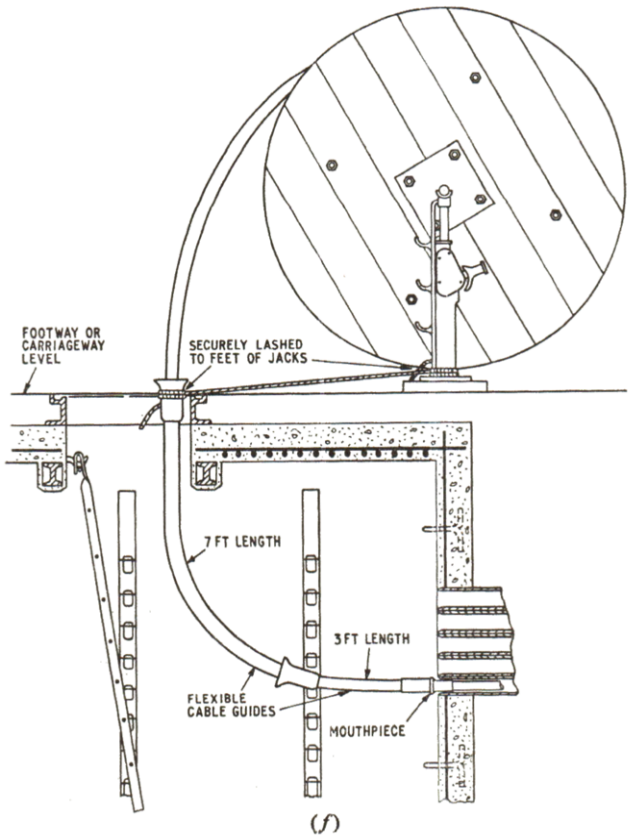
(*d*)

the sheath to prevent the entry of water during the cabling operation. The pulling rope is attached to the cable end by a swivel connector which is screwed onto the shank of the spike and secured in position by a locking nut, see sketch (*e*).



(*e*)

For drawing the cable into a duct via a manhole, the cable drum is set up on jacks or a cable-drum trailer over the end of the duct into which the cable is to be drawn, so that cable may be paid out in a large radius curve from the top of the drum, see sketch (*f*). To prevent



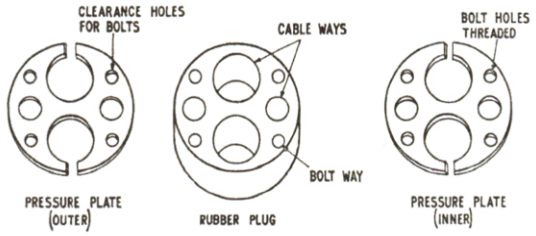
(*f*)

any damage to the cable by contact with rough edges of the manhole or ductway, a flexible guide, securely lashed to the feet of jacks at the manhole entrance, is connected to a bell mouth placed in position at the end of the ductway.

Q. 8. *Describe with the aid of a sketch an expanding-plug type of joint used for small polythene-sheathed cables.*

Sketch the cross-section of a 50-pair, polythene-insulated, polythene-sheathed cable and explain how the wires are identified.

A. 8. The expanding plug consists of a rubber plug sandwiched between two brass pressure plates each having a combination of holes, the size and number of holes depending on type of plug, and held together by four brass bolts, see sketch (*a*). The cables to be jointed are passed through an appropriately-sized hole in the expanding plug,



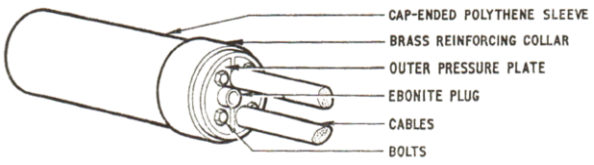
(*a*)

and holes in the plug which are not used are blocked with ebonite plugs.

When the jointing of cable pairs has been completed and the expanding plug correctly positioned on the cables, a cap-ended polythene sleeve is passed over the joint and positioned so that the outer pressure plate of the expanding plug is flush with the end of the sleeve. A brass reinforcing-collar is placed over the end of the sleeve to resist the outward pressure when the expanding plug is tightened. On tightening the four bolts with a spanner, the rubber plug is compressed causing it to expand radially and firmly grip the cables and the inside of the mouth of the sleeve containing the joint.

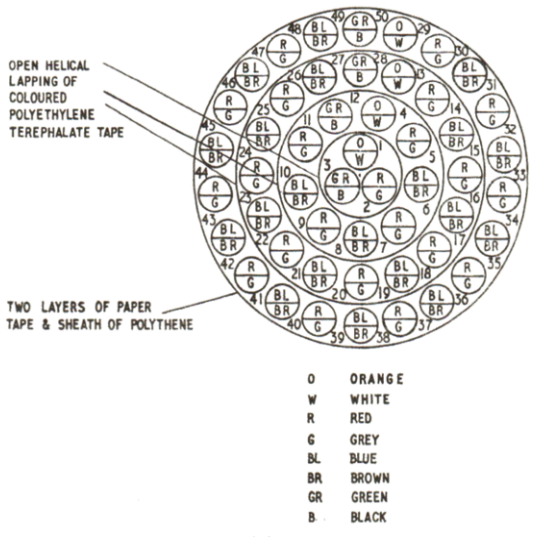
To facilitate pressure testing of joints up to 2 in in diameter one of the securing bolts is replaced by a bolt containing a Schrader valve, for other sizes a Schrader valve is fitted in the sleeve 3 in from the end.

The sealing of the plug can be tested using soap suds while applying an air pressure of 10 lb/in² via the Schrader valve. On completion, all traces of soap should be removed and the reinforcing collar and the heads of the four bolts should be painted. Sketch (*b*) shows an expanding-plug type joint.



(*b*)

The cross-section of a 50-pair, polythene-insulated, polythene-sheathed cable is shown in sketch (*c*). The wires of a 50-pair



(*c*)

polythene cable are identified by the coloured polythene insulation of each pair of wires and their position in the layer formation of the cable.

The cable has 3 centre pairs, 9 first layer pairs, 16 second layer pairs and 22 outer layer pairs; the centre and second layers have a blue open-helical lapping of polyethylene-terephalate tape, the first layer has an orange coloured tape lapping.

A typical colour scheme is as follows:

Centre: first pair, orange-white; second pair, red-grey; third pair, green-black.

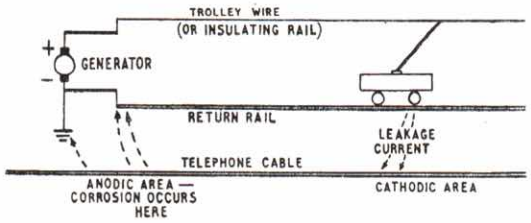
Layers: first pair, orange-white; last pair, green-black; intermediate pairs, alternately red-grey and blue-brown.

The numbering of pairs commences at the centre and continues radially to the last pair of the outer layer. The A-wire is the colour quoted first in each pair.

Q. 9. *Explain how corrosion of the lead sheath of an underground cable can occur when the cable is in a duct route near to a d.c. traction system.*

Describe the appearance of a lead cable sheath which has been corroded by the action of stray currents arising from a d.c. traction system.

A. 9. Stray current leaking to earth from the rails of a d.c. traction system can cause electrolytic corrosion of an underground lead-sheathed telephone cable. The circumstances which can cause such corrosion to occur are illustrated in the sketch.



The rails of the traction system carry the return current from the traction motor to the source of power (the generator). There must therefore be a fall in potential along the rails from the terminus towards the source. At, or near, the end of the track the rails will be positive to the surrounding earth, and current will tend to flow from the rails into the earth. At, or near, the generator the rails will be negative to the surrounding earth, and current will tend to flow from the earth into the rails and so back to the source.

If a lead-sheathed telephone cable runs parallel with the rails, the leakage currents will be picked up by the sheath and current will flow along the sheath from the pick up area towards the generator. At a point near to the generator the current will leave the cable sheath and flow back to the rails. It is at this point that corrosion will occur, since the cable sheath becomes the anode of an electrolytic cell.

The pick-up area is known as the cathodic area and the discharge area, where corrosion occurs, the anodic area.

The effects of electrolytic corrosion are rarely spread evenly along the surface of the lead sheath, but occur over small areas in an irregular manner. Electrolytic corrosion usually appears in the form of pits in the cable sheath. The pits are normally steep-sided and sometimes undercut. They may be distributed at random over a small area or they may take the form of deep furrows. Once the surface of the sheath is pitted, the attack tends to concentrate in the pits, making them deeper and finally puncturing the sheath.

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